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Full-Scale Field Evaluation of Waste Disposal from Coal-Fired Electric Generating Plants
Volume 6. Appendices G through I

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FULL-SCALE FIELD EVALUATION OF WASTE DISPOSAL FROM COAL-FIRED ELECTRIC GENERATING PLANTS

Volume VI. Appendices G Through I

by

Chakra J. Santhanam, Armand A. Balasco,
Itamar Bodek, and Charles B. Cooper

Arthur D. Little, Inc.
20 Acorn Park
Cambridge, MA 02140

EPA Contract: 68-02-3167

John T. Humphrey
Haley and Aldrich, Inc.
238 Main Street
Cambridge, MA 02142

Barry Thacker
Geologic Associates, Inc.
10628 Dutchtown Road
Knoxville, TN 37922

EPA Project Officer: Julian W. Jones
Air and Energy Engineering Research Laboratory
Office of Environmental Engineering and Technology
Research Triangle Park, NC 27711

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

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16. ABSTRACT The six-volume report summarizes results of a 3-year study of current coal ash and flue gas desulfurization (FGD) waste disposal practices at coal-fired electric generating plants. The study involved characterization of wastes, environmental data gathering, evaluation of environmental effects, and engineering/cost evaluations of disposal practices at six sites around the country. Study results provide technical background data and information for EPA, state and local permitting officials, and the utility industry for implementing environmentally sound disposal practices. Study data suggest that no environmental effects have occurred at any of the six sites; i.e., data from wells downgradient of the disposal sites indicate that waste leachate has resulted in concentrations of chemicals less than the EPA primary drinking water standards. A generic environmental evaluation--based on a matrix of four waste types, three disposal methods, and five environmental settings--shows that, on balance, technology exists for environmentally sound disposal of coal ash and FGD wastes for ponding, interim ponding/landfilling, and landfilling. For some combinations of waste types, disposal methods, and environmental settings, mitigation methods must be taken to avoid adverse environmental effects. Costs of waste disposal operations are highly system and site specific.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Ashes	Pollution Control	13B	21B
Waste Disposal	Flue Gases	Stationary Sources	14G	07A, 07D
Wastes	Desulfurization		21D	14A
Coal	Cost Engineering			
Combustion			10B	
Electric Power Plants				

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ABSTRACT

This report summarizes results of a 3-year study of current coal ash and flue gas desulfurization (FGD) waste disposal practices at coal-fired electric generating plants. The study was conducted by Arthur D. Little, Inc., under EPA contract 68-02-3167, and involved characterizing wastes, gathering environmental data, assessing environmental effects, and evaluating the engineering/costs of disposal practices at six selected sites in various locations around the country. Results of the study are providing technical background data and information to EPA, State and local permitting officials, and the utility industry for implementing environmentally sound disposal practices.

Data from the study suggest that no major environmental effects have occurred at any of the six sites. For example, data from wells downgradient of the disposal sites indicate that the contribution of waste leachate to the groundwater has generally resulted in concentrations of chemicals less than the primary drinking water standards established by EPA. Although occasional exceedances of the standards were observed, these were not necessarily attributable to coal ash and FGD waste. A generic environmental evaluation based on a matrix of four waste types, three disposal methods, and five environmental settings (based on climate and hydrogeology) shows that technology exists for environmentally sound disposal of coal ash and FGD wastes for ponding, interim ponding/landfilling, and landfilling. For some combinations of waste types, disposal methods, and environmental settings, measures must be taken to avoid adverse environmental effects. However, site-specific application of good engineering design and practices can mitigate most potentially adverse effects of coal ash and FGD waste disposal. Costs of waste disposal operations are highly system- and site-specific.

APPENDIX G

ENGINEERING/COST DATA

FULL-SCALE FIELD EVALUATION OF WASTE DISPOSAL FROM COAL-FIRED ELECTRIC GENERATING PLANTS

By

Chakra J. Santhanam
Armand A. Balasco
Itamar Bodek
Charles B. Cooper
John T. Humphrey (Haley & Aldrich, Inc.)
and
Barry K. Thacker (Bowser-Morner Testing Laboratories)

Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts 02140

EPA Contract 68-02-3167

EPA Project Officer: Julian W. Jones
Industrial Environmental Research Laboratory*
Office of Environmental Engineering and Technology
Research Triangle Park, North Carolina 27711

Prepared For

U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

(*) Now, Air and Energy Engineering Research Laboratory

APPENDIX G

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TABLE 1

PLANT ALLEN AREA ACCOUNTS

The following series of equipment numbers were assigned to the solid waste handling/disposal system at Plant Allen and are divided among the area accounts specified below:

1100 Series = Plant Allen fly ash handling system

1200 Series = Plant Allen bottom ash handling system

1300 Series = Plant Allen coal ash transport system

1400 Series = Plant Allen coal pile runoff transport system

1500 Series = Plant Allen miscellaneous plant wastes transport system

1600 Series = Plant Allen coal ash/coal pile runoff/miscellaneous plant wastes disposal system

Source: Arthur D. Little, Inc.

TABLE 2

PLANT ALLEN EQUIPMENT LIST

AREA 1100 - PLANT ALLEN FLY ASH HANDLING SYSTEM

Item No.	Description	No. Required
	BLOWERS	
B - 1101 - A/C	Units 3 and 4 Fly Ash Blowers	3
	EDUCTORS	
E - 1101	Unit 1 Fly Ash/Water Hydroveyor Exhauster	1
E - 1102	Unit 2 Fly Ash/Water Hydroveyor Exhauster	1
E - 1103 - A/B	Unit 3 Fly Ash/Water Hydroveyor Exhauster	2
E - 1104 - A/B	Unit 4 Fly Ash/Water Hydroveyor Exhauster	2
E - 1105 - A/D	Unit 5 Fly Ash/Water Hydroveyor Exhauster	4
	VESSELS	
V - 1101	Units 1 and 2 Air Separator Tank	1
V - 1102	Unit 3 Air Separator Tank	1
V - 1103	Unit 4 Air Separator Tank	1
V - 1104 - A/B	Unit 5 Air Separator Tank	2

AREA 1200 - PLANT ALLEN BOTTOM ASH HANDLING SYSTEM

Item No.	Description	No. Required
	EDUCTORS	
E - 1201	Unit 1 Bottom Ash Jet Pump	1
E - 1202	Unit 2 Bottom Ash Jet Pump	1
E - 1203	Unit 3 Bottom Ash Jet Pump	1
E - 1204	Unit 4 Bottom Ash Jet Pump	1
E - 1205	Unit 5 Bottom Ash Jet Pump	1
	PUMPS	
P - 1201	Unit 1 Bottom Ash Service Water Booster Pump	1
P - 1202	Unit 2 Bottom Ash Service Water Booster Pump	1
P - 1203	Unit 3 Bottom Ash Service Water Booster Pump	1
P - 1204	Unit 4 Bottom Ash Service Water Booster Pump	1
P - 1205 - A/B	Unit 5 Bottom Ash Service Water Booster Pump	2

TABLE 2 (Continued)

PLANT ALLEN EQUIPMENT LIST

AREA 1300 - PLANT ALLEN COAL ASH TRANSPORT SYSTEM

Item No.	Description	No. Required
	EDUCTORS	
E - 1301	Sluice Line A Jet Booster Pump	1
E - 1302	Sluice Line B Jet Booster Pump	1
E - 1303	Sluice Line D Jet Booster Pump	1
	PUMPS	
P - 1301 - A/C	Sluice Lines A and B Service Water Booster Pump	3
P - 1302 - A/B	Sluice Line D Service Water Booster Pump	2
P - 1303 - A/G	High Pressure Service Water Pump	7

AREA 1400 - PLANT ALLEN COAL PILE RUNOFF TRANSPORT SYSTEM

	PUMPS	
P - 1401 - A/C	Coal Yard Sump Pump	3

AREA 1500 - PLANT ALLEN MISCELLANEOUS PLANT WASTES TRANSPORT SYSTEM

	PUMPS	
P - 1501 - A/C	Plant Sump Pump	3

AREA 1600 - PLANT ALLEN COAL ASH/COAL PILE RUNOFF/MISCELLANEOUS PLANT WASTES DISPOSAL SYSTEM

	PONDS	
PD - 1601	Disposal Pond A	1
PD - 1602	Disposal Pond B	1
PD - 1603	Disposal Pond C	1

Source: Arthur D. Little, Inc.

TABLE 3

ELRAMA PLANT AREA ACCOUNTS

The following series of equipment numbers were assigned to the solid waste handling/disposal system at the Elrama Plant and are divided among the area accounts specified below:

2100 Series = Elrama Plant fly ash handling system
2200 Series = Elrama Plant fly ash storage system
2300 Series = Elrama Plant bottom ash handling system
2400 Series = Elrama Plant bottom ash transport system
2500 Series = Elrama Plant bottom ash placement/interim disposal system
2600 Series = CS stabilization process raw materials storage/handling
2700 Series = CS FGC waste processing system
2800 Series = CS stabilized FGC waste/bottom ash transport system
2900 Series = CS stabilized FGC waste/bottom ash placement and disposal system

Source: Arthur D. Little, Inc.

TABLE 4

ELRAMA PLANT EQUIPMENT LIST

AREA 2100 - ELRAMA PLANT FLY ASH HANDLING

Item No.	Description	No. Required
	BLOWERS	
B - 2101	Fly Ash Conveying Rotary Air Compressor	1
B - 2102	Fly Ash Conveying Rotary Air Compressor	1
	FEEDERS	
D - 2101	Units 1, 2, and 3 Fly Ash Fluidizing Chamber	1
D - 2102	Unit 4 Fly Ash Fluidizing Chamber	1
	EDUCTORS	
E - 2101	Units 1 and 2 Fly Ash/Water Jet Ejector	1
E - 2102	Units 1 and 2 Fly Ash Hydrovactor	1
E - 2103	Unit 3 Fly Ash Hydrovactor	1
E - 2104	Unit 3 Fly Ash/Water Jet Ejector	1
E - 2105	Unit 4 Fly Ash Hydrovactor	1
E - 2106	Unit 4 Fly Ash/Water Jet Ejector	1
	CYCLONES	
F - 2101	Units 1, 2, and 3 Fly Ash Cyclone	1
F - 2102	Unit 4 Fly Ash Cyclone	1
	VESSELS	
V - 2101	Units 1 and 2 Fly Ash/Air Separator Tank	1
V - 2102	Unit 3 Fly Ash/Air Separator Tank	1
V - 2103	Unit 4 Fly Ash/Air Separator Tank	1

AREA 2200 - ELRAMA PLANT FLY ASH STORAGE SYSTEM

Item No.	Description	No. Required
	COMPRESSORS/FANS	
B - 2201	Ash Silo Scrubber Exhaust Fan	1
B - 2202	Fly Ash Conveying Blower	1

TABLE 4 (Continued)

ELRAMA PLANT EQUIPMENT LIST

AREA 2200 - ELRAMA PLANT FLY ASH STORAGE SYSTEM (Continued)

Item No.	Description	No. Required
	FEEDERS	
D - 2201	Fly Ash Silo Rotary Air Lock Feeder	1
D - 2202 - A/B	Fly Ash Silo Rotary Air Lock Feeder (Manual Op.)	2
D - 2203 - A/B	Fly Ash Silo Unloader (Pugmill)	2
	SCRUBBERS	
F - 2201	Fly Ash Storage Silo Venturi Scrubber	1
	PUMPS	
P - 2201 - A/B	Fly Ash Storage Silo Sump Pump	2
	STORAGE VESSELS	
S - 2201	Fly Ash Storage Silo	1
	SUMPS	
V - 2201	Fly Ash Storage Silo Sump	1

AREA 2300 - ELRAMA PLANT BOTTOM ASH HANDLING SYSTEM

Item No.	Description	No. Required
	AGITATORS	
A - 2301	Bottom Ash Overflow Sump Agitator	1
	SLUICE TRENCHES	
C - 2301	Units 1 and 2 Bottom Ash Sluice Trench	1
C - 2302	Units 3 and 4 Bottom Ash Sluice Trench	1
	STRAINERS	
F - 2301	Rotary Strainer	1
F - 2302	Twin Strainer	1
F - 2303	Rotary Strainer	1

TABLE 4 (Continued)

ELRAMA PLANT EQUIPMENT LIST

AREA 2300 - ELRAMA PLANT BOTTOM ASH HANDLING SYSTEM (Continued)

Item No.	Description	No. Required
	PUMPS	
P - 2301 - A/B	Units 1 and 2 Ash Sluice Water Pump	2
P - 2302	Unit 3 Ash Sluice Water Pump	1
P - 2303 - A/B	Unit 4 Ash Sluice Water Pump	2
	SUMPS	
V - 2301	Bottom Ash Sump	1
V - 2302	Bottom Ash Overflow Sump	1
V - 2303	Surface Water Sump	1

AREA 2400 - ELRAMA PLANT BOTTOM ASH TRANSPORT SYSTEM

Item No.	Description	No. Required
	PUMPS	
P - 2401 - A/B	Bottom Ash Handling Pump	2
P - 2402 - A/B	Bottom Ash Overflow Sump Pump	2
P - 2403 - A/B	Surface Water Sump Pump	2

AREA 2500 - ELRAMA PLANT BOTTOM ASH PLACEMENT/INTERIM DISPOSAL SYSTEM

Item No.	Description	No. Required
	PONDS	
PD - 2501	Interim Bottom Ash Disposal Pond	1
PD - 2502	Interim Bottom Ash Disposal Pond	1
PD - 2503	Polishing Pond	1
	PUMPS	
P - 2501 - A/C	Bottom Ash Disposal Pond Overflow Sump Pump	3
	SUMPS	
V - 2501	Bottom Ash Disposal Pond Overflow Sump	1

TABLE 4 (Continued)

ELRAMA PLANT EQUIPMENT LIST

AREA 2600 - CS STABILIZATION PROCESS RAW MATERIALS STORAGE/HANDLING

Item No.	Description	No. Required
	BLOWERS	
B - 2601	Lime Baghouse Exhaust Blower	1
B - 2602	Fly Ash Baghouse Exhaust Blower	1
B - 2603	Bag Cleaning Air Compressor	1
	CONVEYORS	
C - 2601	Lime Screw Conveyor	1
C - 2602	Fly Ash Screw Conveyor	1
	FEEDERS	
D - 2601	Lime Storage Silo Screw Feeder	1
D - 2602	Fly Ash Storage Silo Rotary Air Lock Feeder	1
D - 2603	Fly Ash Storage Silo Screw Feeder	1
	BAGHOUSES	
F - 2601	Lime Storage Silo Baghouse	1
F - 2602	Fly Ash Storage Silo Baghouse	1
	SCALES	
H - 2601	Lime Scale	1
H - 2602	Fly Ash Scale	1
	STORAGE BINS	
S - 2601	Lime Storage Silo with Live Bin	1
S - 2602	Fly Ash Storage Silo with Live Bin	1

TABLE 4 (Continued)

ELRAMA PLANT EQUIPMENT LIST

AREA 2700 - CS FGC WASTE PROCESSING SYSTEM

Item No.	Description	No. Required
	AGITATORS	
A - 2701	FGD Sludge Distribution Tank Agitator	1
A - 2702	FGD Sludge Surge Tank Agitator	1
	BLOWERS	
B - 2701	Pugmill Baghouse Exhaust Blower	1
	CONVEYORS	
C - 2701 - A/B	Filter Cake Belt Conveyor (Drum Discharge)	2
C - 2702	Filter Cake Belt Conveyor (Mixer Feed)	1
C - 2703	Processed Waste Belt Conveyor (Mixer Discharge)	1
C - 2704	Processed Waste Belt Conveyor (Radial Stacker)	1
C - 2705	Pugmill Bypass Belt Conveyor	1
	FILTERS	
F - 2701 - A/B	Rotary Drum Vacuum Filter	2
F - 2702	Pugmill Baghouse	1
	MIXERS	
M - 2701	Pugmill	1
	PUMPS	
P - 2701 - A/C	Thickener Underflow Pump	3
P - 2702 - A/C	Thickener Overflow Pump	3
P - 2703	Excess Thickener Overflow Pump	1
P - 2704 - A/C	FGD Sludge Surge Tank Pump	3
P - 2705 - A/B	Rotary Drum Filter Vacuum Pump	2
P - 2706 - A/B	Filtrate Recycle Pump	2
P - 2707 - A/B	Filtrate Pump	2
	THICKENERS	
T - 2701 - A/B	FGD Sludge Thickener	2

TABLE 4 (Continued)

ELRAMA PLANT EQUIPMENT LIST

AREA 2700 - CS FGC WASTE PROCESSING SYSTEM (Continued)

Item No.	Description	No. Required
	VESSELS	
V - 2701	FGD Sludge Distribution Tank	1
V - 2702	FGD Sludge Thickener Overflow Sump	1
V - 2703	FGD Sludge Surge Tank	1
	AREA 2800 - CS STABILIZED FGC WASTE/BOTTOM ASH TRANSPORT SYSTEM	
	MOBILE EQUIPMENT	
Fl - 2801	Front End Loader	1
Tr - 2801 - A/T	Dump Truck	20
	AREA 2900 - CS STABILIZED WASTE/BOTTOM ASH PLACEMENT AND DISPOSAL SYSTEM	
	DISPOSAL OPERATION	
LF - 2901	Landfill	1
PD - 2901	Runoff Settling Pond	1
PD - 2902	Runoff Settling Pond	1
PD - 2903	Runoff Settling Pond	1
	MOBILE EQUIPMENT	
Dz - 2901 - A/B	Dozer	2
Dz - 2902	Dozer	1
Tr - 2901	Watering Truck	1
Tr - 2902	Motor Grader	1
Tr - 2903	Compactor	1
Tr - 2904	Road Sweeper	1

Source: Arthur D. Little, Inc.

TABLE 5

DAVE JOHNSTON PLANT AREA ACCOUNTS

The following series of equipment numbers were assigned to the dry fly ash waste handling/disposal system at the Dave Johnston Plant and are divided among the area accounts specified below:

3100 Series = Dave Johnston Plant dry fly ash handling system

3200 Series = Dave Johnston Plant dry fly ash storage system

3300 Series = Dave Johnston Plant dry fly ash transport system

3400 Series = Dave Johnston Plant dry fly ash disposal system

Source: Arthur D. Little, Inc.

TABLE 6

DAVE JOHNSTON PLANT EQUIPMENT LIST

AREA 3100 - DAVE JOHNSTON DRY FLY ASH HANDLING SYSTEM

Item No.	Description	No. Required
	BLOWERS	
B - 3101 - A/B	Unit 1 ESP Hopper Fluidizing Blower	2
B - 3102	Unit 2 ESP Hopper Fluidizing Blower	1
B - 3103 - A/B	Unit 3 ESP Hopper Fluidizing Blower	2
B - 3104 - A/B	Unit 1 Fly Ash Conveying Blower	2
B - 3105	Unit 2 Fly Ash Conveying Blower	1
B - 3106 - A/B	Unit 3 Fly Ash Conveying Blower	2
B - 3107 - A/C	Unit 3 Economizer Ash Conveying Blower	3
B - 3108 - A/B	Unit 4 Economizer Ash Conveying Blower	2
	FEEDERS	
D - 3101 - A/X	Unit 1 ESP Hopper Feeder	24
D - 3102 - A/X	Unit 2 ESP Hopper Feeder	24
D - 3103 - A/VV	Unit 3 ESP Hopper Feeder	48
D - 3104 - A/H	Unit 3 Economizer Hopper Feeder	8
D - 3105 - A/F	Unit 4 Economizer Hopper Feeder	6

AREA 3200 - DAVE JOHNSTON PLANT DRY FLY ASH STORAGE SYSTEM

Item No.	Description	No. Required
	BLOWERS	
B - 3201 - A/B	Fly Ash Storage Bin Vent Fan	2
B - 3202 - A/B	Fly Ash Storage Bin Vent Fan	2
B - 3203	Fly Ash Storage Bin Fluidizing Blower	1
B - 3204	Fly Ash Storage Bin Fluidizing Blower	1
	FEEDERS	
D - 3201 - A/B	Fly Ash Storage Bin Unloader	2
D - 3202 - A/B	Fly Ash Storage Bin Unloader	2
	STORAGE VESSELS	
S - 3201	Fly Ash Storage Bin	1
S - 3202	Fly Ash Storage Bin	1

TABLE 6 (Continued)

DAVE JOHNSTON PLANT EQUIPMENT LIST

AREA 3300 - DAVE JOHNSTON PLANT DRY FLY ASH TRANSPORT SYSTEM

Item No.	Description	No. Required
	MOBILE EQUIPMENT	
Tr - 3301 - A/B	Haulpak Truck	2

AREA 3400 - DAVE JOHNSTON PLANT DRY FLY ASH DISPOSAL SYSTEM

Item No.	Description	No. Required
	LANDFILL	
LF -3401	Dry Fly Ash Landfill	1
	MOBILE EQUIPMENT	
Dz - 3401	Dozer	1
Tr - 3401	Water Wagon	1
Tr - 3402	Water Wagon	1

Source: Arthur D. Little, Inc.

TABLE 7

SHERBURNE COUNTY PLANT AREA ACCOUNTS

The following series of equipment numbers were assigned to the solid waste handling/disposal system at the Sherco site and are divided among the area accounts specified below:

4100 Series = Sherco Plant fly ash/FGD waste processing system

4200 Series = Sherco Plant fly ash/FGD waste transport system

4300 Series = Sherco Plant fly ash/FGD waste disposal system

4400 Series = Sherco Plant scrubber recycle water system

4500 Series = Sherco Plant bottom ash/pyrites handling system

4600 Series = Sherco Plant bottom ash/pyrites transport system

4700 Series = Sherco Plant bottom ash/pyrites disposal system

4800 Series = Sherco Plant bottom ash/pyrites sluice water system recycle

4900 Series = Sherco Plant coal pile runoff/plant wastes transport

Source: Arthur D. Little, Inc.

TABLE 8

SHERBURNE COUNTY PLANT EQUIPMENT LIST

AREA 4100 - SHERBURNE COUNTY PLANT FLY ASH/FGD WASTE PROCESSING SYSTEM

Item No.	Description	No. Required
	EDUCTORS	
E-4101	Unit 1 Economizer Ash Jet Exhauster	1
E-4102	Unit 2 Economizer Ash Jet Exhauster	1
	PUMPS	
P-4101-A/L	Unit 1 Scrubber Bleed Pumps	12
P-4102-A/L	Unit 2 Scrubber Bleed Pumps	12
P-4103-A/D	Unit 1 Scrubber Drain Pumps	4
P-4104-A/D	Unit 2 Scrubber Drain Pumps	4
P-4105-A/D	Scrubber Sump Pumps	4
	THICKENERS	
T-4101-A/B	Thickener	2
	VESSELS	
V-4101	Unit 1 Slurry Transfer Tank	1
V-4102	Unit 2 Slurry Transfer Tank	1
V-4103	Unit 1 Boil Box	1
V-4104	Unit 2 Boil Box	1

AREA 4200 - SHERBURNE COUNTY PLANT FLY ASH/FGD WASTE TRANSPORT SYSTEM

P-4201-A/D	Thickener Sludge Pumps	4

AREA 4300 - SHERBURNE COUNTY PLANT FLY ASH/FGD WASTE DISPOSAL SYSTEM

PD-4301	Fly Asg/FGD Waste Disposal Pond	1
PD-4302	Scrubber Recycle Pond	1

AREA 4400 - SHERBURNE COUNTY PLANT SCRUBBER RECYCLE WATER SYSTEM

	PUMPS	
P-4401-A/B	Scrubber Makeup Water Pumps	2
P-4402-A/B	Unit 1 Scrubber Recirculation Pumps	2
P-4403-A/B	Unit 2 Scrubber Recirculation Pumps	2
P-4404-A/B	Unit 1 Economizer Ash Water Pumps	2
P-4405-A/B	Unit 2 Economizer Ash Water Pumps	2

TABLE 8 (continued)

SHERBURNE COUNTY PLANT EQUIPMENT LIST

AREA 4400 - SHERBURNE COUNTY PLANT SCRUBBER RECYCLE WATER SYSTEM (continued)

Item No.	Description	No. Required
	VESSELS	
V-4401	Unit 1 Scrubber Recirculation Water Tank	1
V-4402	Unit 2 Scrubber Recirculation Water Tank	1

AREA 4500 - SHERBURNE COUNTY PLANT BOTTOM ASH/PYRITES HANDLING SYSTEM

Item No.	Description	No. Required
	EDUCTORS	
E-4501-A/G	Unit 1 Pyrite Jet Pumps	7
E-4502-A/G	Unit 2 Pyrite Jet Pumps	7
E-4503-A/F	Unit 1 Bottom Ash Jet Pumps	6
E-4504-A/F	Unit 2 Bottom Ash Jet Pumps	6

AREA 4600 - SHERBURNE COUNTY PLANT BOTTOM ASH/PYRITES TRANSPORT SYSTEM

No processing equipment is assigned to this account.

AREA 4700 - SHERBURNE COUNTY PLANT BOTTOM ASH/PYRITES DISPOSAL SYSTEM

Item No.	Description	No. Required
PD-4701	Bottom Ash Disposal Pond	1
PD-4702	Bottom Ash Recycle Pond	1

AREA 4800 - SHERBURNE COUNTY PLANT BOTTOM ASH/PYRITES SLUICE WATER RECYCLE SYSTEM

Item No.	Description	No. Required
	PUMPS	
P-4801-A/C	Recycle Water Pumps	3
P-4802-A/B	Pyrite Sluice Water Pumps	2
P-4803-A/B	Bottom Ash Sluice Water Pumps	2
P-4804-A/B	Recycle Seal Water Pumps	2

AREA 4900 - SHERBURNE COUNTY PLANT COAL PILE RUNOFF/PLANT WASTES TRANSPORT SYSTEM

No processing equipment is assigned to this account.

Source: Arthur D. Little, Inc.

TABLE 9

POWERTON PLANT AREA ACCOUNTS

The following series of equipment numbers were assigned to the solid waste handling/disposal system at the Powerton Plant and are divided among the area accounts specified below:

5100 Series = Powerton Plant fly ash handling system

5200 Series = Powerton Plant fly ash storage system

5300 Series = Powerton Plant slag handling system

5400 Series = Powerton Plant economizer ash handling system

5500 Series = Powerton Plant fly ash/slag/economizer ash transport system

5600 Series = Powerton Plant fly ash/bottom ash/economizer ash disposal system

5700 Series = Powerton Plant ash sluice water treatment system

5800 Series = Powerton Plant miscellaneous plant wastes handling system

Source: Arthur D. Little, Inc.

TABLE 10

POWERTON PLANT EQUIPMENT LIST

AREA 5100 - POWERTON PLANT FLY ASH HANDLING SYSTEM

Item No.	Description	No. Required
	BLOWERS	
B-5101-A/C	Vacuum Pump	3
B-5102-A/C	Vacuum Pump	3
	AREA 5200 - POWERTON PLANT FLY ASH STORAGE SYSTEM	
	BLOWERS	
B-5201-A/B	Fly Ash Fluidizing Blower	2
B-5202-A/B	Fly Ash Fluidizing Blower	2
	FEEDERS	
D-5201-A/L	Fly Ash Diffuser	12
D-5202-A/L	Fly Ash Diffuser	12
	CYCLONES/BAGFILTERS	
F-5201-A/C	Cyclone	3
F-5202-A/C	Bag Filter	3
F-5203-A/C	Cyclone	3
F-5204-A/C	Bag Filter	3
	MIXERS	
M-5201-A/B	Mixer/Rotary Unloader	2
M-5202-A/B	Mixer/Rotary Unloader	2
	STORAGE VESSELS	
S-5201	Unit 5 Fly Ash Storage Silo	1
S-5202	Unit 6 Fly Ash Storage Silo	1
S-5203-A/B	Unloading Chute	2
S-5204-A/B	Unloading Chute	2
	AREA 5300 - POWERTON PLANT SLAG HANDLING SYSTEM	
	EDUCTORS	
E-5301-A/D	Jet Pump	4
E-5302-A/D	Jet Pump	4

TABLE 10 (continued)

POWERTON PLANT EQUIPMENT LIST

AREA 5300 - POWERTON PLANT SLAG HANDLING SYSTEM (continued)

Item No.	Description	No. Required
	DEWATERING BINS	
F-5301-A/B	Unit 5 Slag Dewatering Bin	2
F-5302-A/B	Unit 6 Slag Dewatering Bin	2
	GRINDERS	
G-5301-A/D	Unit 5 Slag Breaker	4
G-5302-A/D	Unit 6 Slag Breaker	4
	PUMPS	
P-5301-A/C	Unit 5 Ash Sluice Pump	3
P-5302-A/C	Unit 6 Ash Sluice Pump	3
	AREA 5400 - POWERTON PLANT ECONOMIZER ASH HANDLING SYSTEM	
	EDUCTORS	
E-5401-A/B	Jet Pump	2
E-5402-A/B	Jet Pump	2
E-5403-A/B	Jet Pump	2
E-5404-A/B	Jet Pump	2
	VESSELS	
V-5401-A/B	Unit 5 Economizer Ash Auxiliary Hopper	2
V-5402-A/B	Unit 5 Economizer Ash Auxiliary Hopper	2
V-5403-A/B	Unit 6 Economizer Ash Auxiliary Hopper	2
V-5404-A/B	Unit 6 Economizer Ash Auxiliary Hopper	2
	AREA 5500 - POWERTON PLANT FLY ASH/SLAG/ECONOMIZER ASH TRANSPORT SYSTEM	
	MOBILE EQUIPMENT	
Tr-5501-A/F	Truck	6
	AREA 5600 - POWERTON PLANT FLY ASH/SLAG/ECONOMIZER ASH DISPOSAL SYSTEM	
	LANDFILLS	
LF-5601	Landfill (retired)	1
LF-5602	Landfill (retired)	1

TABLE 10 (continued)

POWERTON PLANT EQUIPMENT LIST

AREA 5600 - POWERTON PLANT FLY ASH/SLAG/ECONOMIZER ASH DISPOSAL SYSTEM (continued)

Item No.	Description	No. Required
	MOBILE EQUIPMENT	
Dz-5601	Dozer	1
Fl-5602	Front End Loader	1
	SETTLING PONDS	
PD-5601	Settling Pond	1
PD-5602	Auxiliary Settling Pond	1
	AREA 5700 - POWERTON PLANT SLUICE WATER TREATMENT SYSTEM	
	PUMPS	
P-5701-A/C	Settling Pond Overflow Sump Pump	3
P-5702-A/C	Service Water Supply Sump Pump	3
	VESSELS (SUMPS)	
V-5701	Settling Pond Overflow Sump	1
V-5702	Service Water Sump	1
	AREA 5800 - POWERTON PLANT MISCELLANEOUS PLANT WASTES HANDLING SYSTEM	
	PUMPS	
P-5801-A/D	Unit 5 Slag Overflow Sump Pump	4
P-5802-A/D	Unit 6 Slag Overflow Sump Pump	4
P-5803-A/B	Demineralizer Filter Sump Pump	2
P-5804-A/B	Ash Sluice Line Drain Sump Pump	2
	VESSELS (SUMPS)	
V-5801-A/B	Unit 5 Slag Overflow Sump	2
V-5802-A/B	Unit 6 Slag Overflow Sump	2
V-5803-A/B	Demineralizer Filter Backwash Sump	2
V-5804	Bottom Ash Sluice Line Drain Sump	1

Source: Arthur D. Little, Inc.

TABLE 11

LANSING SMITH PLANT AREA ACCOUNTS

The following series of equipment numbers were assigned to the solid waste handling/disposal system at Lansing Smith Plant and are divided among the area accounts specified below:

6100 Series = Lansing Smith Plant fly ash handling/transport system

6200 Series = Lansing Smith Plant bottom ash/mill rejects handling/transport system

6300 Series = Lansing Smith Plant coal pile runoff transport system

6400 Series = Lansing Smith Plant miscellaneous plant wastes transport system

6500 Series = Lansing Smith Plant coal ash/coal pile runoff/miscellaneous plant wastes disposal system

6600 Series = Lansing Smith Plant coal ash sluice water recycle system

Source: Arthur D. Little, Inc.

TABLE 12

LANSING SMITH PLANT EQUIPMENT LIST

AREA 6100 - LANSING SMITH FLY ASH HANDLING AND TRANSPORT SYSTEM

Item No.	Description	No. Required
	EDUCTORS	
E-6101	Unit 1 Fly Ash/Water Jet Ejector	1
E-6102	Unit 2 Fly Ash/Water Jet Ejector	1
	VESSELS	
V-6101	Unit 1 Air Separator Tank	1
V-6102	Unit 2 Air Separator Tank	1
	PUMPS	
P-6101-A/B	Units 1 and 2 Fly Ash Service Water Booster Pump	2 (one for each unit)

AREA 6200 - LANSING SMITH PLANT BOTTOM ASH/MILL REJECTS HANDLING AND TRANSPORT SYSTEM

Item No.	Description	No. Required
	EDUCTORS	
E-6201	Unit 1 Bottom Ash Jet Pump	1
E-6202	Unit 2 Bottom Ash Jet Pump	1
E-6203-A/D	Unit 1 Mill Rejects Jet Pump	4
E-6204-A/E	Unit 2 Mill Rejects Jet Pump	5
	VESSELS	
V-6201-A/D	Unit 1 Mill Rejects Storage/Transfer Hopper	4
V-6202-A/E	Unit 2 Mill Rejects Storage/Transfer Hopper	5
	PUMPS	
P-6201-A/B	Units 1 and 2 Bottom Ash Service Water Booster Pump	2 (one for each unit)
P-6202	Units 1 and 2 Mill Rejects Service Water Booster Pump	1 (services both units)

TABLE 12 (continued)

LANSING SMITH PLANT EQUIPMENT LIST

AREA 6300 - LANSING SMITH PLANT COAL PILE RUNOFF TRANSPORT SYSTEM

Item No.	Description	No. Required
	PUMPS	
P-6301	Coal Yard Sump Pump	1
P-6302	Coal Yard Sump Pump	1
P-6303	Coal Yard Sump Pump	1
	SUMPS	
V-6301	Coal Yard Sump	1
V-6302	Coal Yard Sump	1
V-6303	Coal Yard Sump	1

AREA 6400 - LANSING SMITH PLANT MISCELLANEOUS PLANT WASTES TRANSPORT SYSTEM

	PUMPS	
P-6401-A/C	Plant Sump Pump	3 (inside)
P-6402-A/B	Plant Sump Pump	2 (outside)
P-6403	Demineralizer/Blowdown Waste Pump	1
P-6404	Clarified Demineralizer/Blowdown Waste Pump	1
	SUMPS/VESSELS	
V-6401	Plant Sump	1
V-6402	Demineralizer/Blowdown Waste Tank	1

AREA 6500 - LANSING SMITH PLANT COAL ASH/COAL PILE RUNOFF/MISCELLANEOUS PLANT WASTES DISPOSAL SYSTEM

	PONDS	
PD-6501	Boiler Cleaning Waste Disposal Pond	1
PD-6502	Demineralizer/Blowdown Waste Disposal Pond	1
PD-6503	Coal Ash/Coal Pile Runoff/Plant Waste Disposal Pond	1

TABLE 12 (continued)

LANSING SMITH PLANT EQUIPMENT LIST

AREA 6600 - LANSING SMITH PLANT COAL ASH SLUICE WATER RECYCLE SYSTEM

Item No.	Description	No. Required
	PUMPS	
P-6601-A/B	Recycle Service Water Pump (recycles water from canal to plant)	2

Source: Arthur D. Little, Inc.

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TABLE 13

DETAILED CAPITAL COST ESTIMATE

Plant Name: Allen
Plant Location: Gaston County, North Carolina
Utility Name: Duke Power Company
Nameplate Generating Capacity (MW): 1155

Basis: Late 1982 Estimates
ENR Index = 3931.11 (1913 = 100)
= 365.97 (1967 = 100)

Capital Costs (thousands of $)

		Area 1100	Area 1200	Area 1300		Area 1400	Area 1500	Area 1600		
	Air Pollution Control	Fly Ash Handling and Processing	Bottom Ash Handling and Processing	Fly Ash Transport	Bottom Ash Transport	Coal Pile Runoff Transport	Miscellaneous Plant Waste Handling and Transport	Placement and Fly Ash Disposal	Placement and Bottom Ash Disposal	Total
Direct Costs										
Process Equipment	48,127	176	168	262	97	59	59	–	–	48,948
Piping and Insulation	28	1,234	126	3,390	1,254	178	178	74	28	6,490
Foundations and Structures	4,364	36	9	99	37	28	58	137	51	4,819
Site Preparation and Earthwork	–	–	–	–	–	–	–	8,613	3,185	11,798
Electrical	1,120	214	296	524	194	204	203	25	9	2,789
Instrumentation	280	387	131	32	11	38	39	21	7	946
Buildings	–	–	–	–	–	–	–	–	–	–
Subtotal	53,919	2,047	730	4,307	1,593	507	537	8,870	3,280	75,790
Site Monitoring Wells	–	–	–	–	–	–	–	12	5	17
Reclamation	–	–	–	–	–	–	–	1,380	510	1,890
Services and Miscellaneous	–	41	15	87	32	10	11	178	66	440
Mobile Equipment	–	–	45	–	–	–	–	–	–	45
Total Direct Investment	53,919	2,088	790	4,394	1,625	517	548	10,440	3,861	78,182
Indirect Costs										
Contractors Overhead	5,392	313	119	659	244	78	82	1,357	502	8,746
Contractors Profit	1,078	104	40	220	81	26	27	452	167	2,195
Subtotal	60,389	2,506	949	5,273	1,950	621	657	12,249	4,530	89,123
Engineering Design and Supervision	3,019	251	95	527	195	62	66	1,086	402	5,703
Architect-Engineering Fee	1,208	125	47	263	98	31	33	543	201	2,549
Subtotal	64,616	2,881	1,091	6,063	2,243	714	756	13,878	5,133	97,375
Contingency	19,471	870	331	1,828	676	218	230	3,746	1,385	28,755
Total Fixed Investment	84,087	3,751	1,422	7,891	2,919	932	986	17,624	6,518	126,130
Startup and Modifications	286	20	11	29	11	11	11	–	–	379
Interest During Construction (excluded)	–	–	–	–	–	–	–	–	–	–
Total Depreciable Investment	84,373	3,771	1,433	7,920	2,930	943	997	17,624	6,518	126,509
Other Costs										
Land	–	–	–	–	–	–	–	735	272	1,007
Working Capital (excluded)	–	–	–	–	–	–	–	–	–	–
Total Capital Investment	$84,373	$3,771	$1,433	$7,920	$2,930	$943	$997	$18,359	$6,790	$127,516 ($110/kW)

Source: Arthur D. Little, Inc., estimates.

TABLE 14

DETAILED CAPITAL COST ESTIMATE

Plant Name: Elrama
Plant Location: Washington County, Pennsylvania
Utility Name: Duquesne Light Company
Nameplate Generation Capacity (MW): 510

Basis: Late 1982 Estimates
ENR Index = 3931.11 (1913 = 100)
= 365.97 (1967 = 100)

Capital Costs (thousands of $)

		Area 2100	Area 2200	Area 2300	Area 2400	Area 2500	Area 2600	Area 2700		Area 2800			Area 2900			
	Air Pollution Control	Fly Ash Handling and Processing (Dry)	Fly Ash Storage	Bottom Ash Handling and Processing (Wet)	Bottom Ash Transport (Wet)	Bottom Ash Interim Pond	Raw Material Handling and Storage	Fly Ash Handling and Processing (Wet)	FGD Waste Handling and Processing	Fly Ash Transport (Dry)	Bottom Ash Transport (Dry)	FGD Waste Transport (Dry)	Fly Ash Placement and Disposal	Bottom Ash Placement and Disposal	FGD Waste Placement and Disposal	Total
Direct Costs																
Process Equipment		176	965	225	125	22	133	1,703	4,170	–	–	–	–	–	–	7,519
Piping and Insulation		251	387	125	795	667	31	32	80	–	–	–	–	–	–	2,368
Foundations and Structures		12	28	43	2	41	9	180	442	–	–	–	–	–	–	757
Site Preparation and Earthwork		–	–	–	–	793	–	2	4	–	–	–	1,269	366	516	2,950
Electrical		137	145	224	157	129	144	105	257	–	–	–	–	–	–	1,298
Instrumentation		96	103	111	188	52	63	46	113	–	–	–	–	–	–	772
Buildings		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Subtotal	79,027	672	1,628	728	1,267	1,704	380	2,068	5,066	–	–	–	1,269	366	516	94,691
Site Monitoring Wells	–	–	–	–	–	–	–	–	–	–	–	–	17	5	6	28
Reclamation	–	–	–	–	–	–	–	–	–	–	–	–	845	244	344	1,433
Services and Miscellaneous	–	13	33	15	26	34	7	41	101	–	–	–	25	7	11	313
Mobile Equipment	–	–	–	–	–	–	–	–	–	939	326	651	486	140	198	2,740
Total Direct Investment	79,027	685	1,661	743	1,293	1,738	387	2,109	5,167	939	326	651	2,642	762	1,075	99,205
Indirect Costs																
Contractors Overhead	7,903	103	249	111	194	261	58	317	775	–	–	–	194	56	79	10,300
Contractors Profit	1,581	34	83	37	65	87	20	106	258	–	–	–	65	19	26	2,381
Subtotal	88,511	822	1,993	891	1,552	2,086	465	2,532	6,200	939	326	651	2,901	837	1,180	111,886
Engineering Design and Supervision	4,426	82	200	90	156	209	46	253	620	–	–	–	155	45	63	6,345
Architect-Engineering Fee	1,771	41	100	45	77	104	24	127	310	–	–	–	78	22	32	2,731
Subtotal	94,708	945	2,293	1,026	1,785	2,399	535	2,912	7,130	939	326	651	3,134	904	1,275	120,962
Contingency	28,505	284	688	308	536	720	161	877	2,146	282	97	196	682	197	277	35,956
Total Fixed Investment	123,213	1,229	2,981	1,334	2,321	3,119	696	3,789	9,276	1,221	423	847	3,816	1,101	1,552	156,918
Startup and Modifications	309	1	1	1	1	–	1	10	25	–	–	–	–	–	–	349
Interest During Construction (excluded)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Depreciable Investment	123,522	1,230	2,982	1,335	2,322	3,119	697	3,799	9,301	1,221	423	847	3,816	1,101	1,552	157,267
Other Costs																
Land	–	–	–	–	–	30	–	2	4	–	–	–	381	110	162	689
Working Capital (excluded)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Capital Investment	$123,522	$1,230	$2,982	$1,335	$2,322	$3,149	$697	$3,801	$9,305	$1,221	$423	$847	$4,197	$1,211	$1,714	$157,956 ($310/kW)

Source: Arthur D. Little, Inc., estimates.

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TABLE 15

DETAILED CAPITAL COST ESTIMATE

Plant Name: Dave Johnston
Plant Location: Converse County, Wyoming
Utility Name: Pacific Power & Light Company
Nameplate Generating Capacity (MW): 420

Basis: Late 1982 Estimates
ENR Index = 3931.11 (1913 = 100)
= 365.97 (1967 = 100)

	Capital Costs (thousands of $)					
		Area 3100	Area 3200	Area 3300	Area 3400	
Direct Costs	Air Pollution Control	Fly Ash Handling and Processing	Fly Ash Storage	Fly Ash Transport	Fly Ash Placement and Disposal	Total
Process Equipment	25,438	1,509	1,248	–	–	28,195
Piping and Insulation	16	1,131	29	–	–	1,176
Foundations and Structures	2,545	23	106	–	–	2,674
Site Preparation and Earthwork	–	–	1	–	1,768	1,769
Electrical	385	167	43	–	–	595
Instrumentation	130	940	–	–	–	1,070
Buildings	–	–	–	–	–	–
Subtotal	28,514	3,770	1,427	–	1,768	35,479
Site Monitoring Wells	–	–	–	–	17	17
Reclamation	–	–	–	–	845	845
Services and Miscellaneous	570	75	29	–	35	709
Mobile Equipment	–	–	–	530	354	884
Total Direct Investment	**29,084**	**3,845**	**1,456**	**530**	**3,019**	**37,934**
Indirect Costs						
Contractors Overhead	2,909	577	218	–	270	3,974
Contractors Profit	581	192	73	–	90	936
Subtotal	32,574	4,614	1,747	530	3,379	42,844
Engineering Design & Supervision	1,629	462	75	–	216	2,382
Architect-Engineering Fee	651	231	87	–	108	1,077
Subtotal	34,854	5,307	1,909	530	3,703	46,303
Contingency	10,488	1,595	603	159	852	13,697
Total Fixed Investment	**45,342**	**6,902**	**2,512**	**689**	**4,555**	**60,000**
Startup and Modifications	106	10	–	–	–	116
Interest During Construction (excluded)	–	–	–	–	–	–
Total Depreciable Investment	**45,448**	**6,912**	**2,512**	**689**	**4,555**	**60,116**
Other Costs						
Land	–	–	–	–	41	41
Working Capital (excluded)	–	–	–	–	–	–
Total Capital Investment	**$45,448**	**$6,912**	**$2,512**	**$689**	**$4,596**	**$60,157** **($143/kW)**

Source: Arthur D. Little, Inc., estimates.

TABLE 16

DETAILED CAPITAL COST ESTIMATE

Plant Name: Sherburne County
Plant Location: Sherburne County, Minnesota
Utility Name: Northern States Power Company
Nameplate Generating Capacity (MW): 1458

Basis: Late 1982 Estimates
ENR Index = 3931.11 (1913 = 100)
= 365.97 (1967 = 100)

Capital Costs (thousands of $)

			Area 4100		Area 4200		Area 4300		Area 4400		Area 4500	Area 4600	Area 4700	Area 4800	Area 4900	
	Particulate Control	SO_2 Control	Fly Ash Handling and Processing	FGD Waste Handling and Processing	Fly Ash Transport	FGD Waste Transport	Fly Ash Placement and Disposal	FGD Waste Placement and Disposal	Fly Ash Recycle Water System	FGD Waste Recycle Water System	Bottom Ash Handling and Processing	Bottom Ash Transport	Bottom Ash Placement and Disposal	Bottom Ash Recycle Water System	Coal Pile Runoff and Plant Waste Handling and Transport	Total
Direct Costs																
Process Equipment			4,659	1,811	86	34	27	10	207	80	42	–	37	230	–	7,223
Piping and Insulation			149	58	525	204	148	58	806	314	15	529	361	848	–	4,016
Foundations and Structures			493	191	–	–	330	128	6	2	2	–	327	9	–	1,488
Site Preparation and Earthwork			–	–	–	–	9,300	3,617	–	–	–	–	5,505	–	27	18,449
Electrical			242	94	–	–	68	26	204	80	–	–	94	257	–	1,065
Instrumentation			111	43	21	8	11	4	223	87	1	17	15	204	–	745
Buildings			–	–	–	–	–	–	–	–	–	–	–	–	–	–
Subtotal	97,200	37,800	5,654	2,197	632	246	9,884	3,843	1,446	563	60	546	6,339	1,548	27	167,985
Site Monitoring Wells	–	–	–	–	–	–	9	4	–	–	–	–	4	–	–	17
Reclamation	–	–	–	–	–	–	617	247	–	–	–	–	258	–	–	1,122
Services and Miscellaneous	–	–	113	44	13	5	198	77	29	11	2	8	127	31	1	659
Mobile Equipment	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Direct Investment	97,200	37,800	5,767	2,241	645	251	10,708	4,171	1,475	574	62	554	6,728	1,579	28	169,783
Indirect Costs																
Contractors Overhead	9,734	3,786	865	336	97	37	1,512	588	222	86	9	83	970	237	4	18,566
Contractors Profit	1,947	757	288	112	32	13	504	196	74	29	3	28	323	78	1	4,385
Subtotal	108,881	42,343	6,920	2,689	774	301	12,724	4,955	1,771	689	74	665	8,021	1,894	33	192,734
Engineering Design and Supervision	5,451	2,120	692	269	77	30	1,210	470	177	69	7	67	776	189	3	11,607
Architect-Engineering Fee	2,180	848	346	134	40	15	605	235	89	34	4	33	388	95	2	5,048
Subtotal	116,512	45,311	7,958	3,092	891	346	14,539	5,660	2,037	792	85	765	9,185	2,178	38	209,389
Contingency	35,019	13,618	2,385	930	267	104	4,174	1,623	611	238	26	230	2,677	654	11	62,567
Total Fixed Investment	151,531	58,929	10,343	4,022	1,158	450	18,713	7,283	2,648	1,030	111	995	11,862	2,832	49	271,956
Startup and Modifications	72	28	7	3	–	–	–	–	1	–	–	–	–	1	–	112
Interest During Construction (excluded)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Depreciable Investment	151,603	58,957	10,350	4,025	1,158	450	18,713	7,283	2,649	1,030	111	995	11,862	2,833	49	272,068
Other Costs																
Land	–	–	4	1	–	–	314	116	–	–	–	–	118	–	–	553
Working Capital (excluded)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Capital Investment	$151,603	$58,957	$10,354	$4,026	$1,158	$450	$19,027	$7,399	$2,649	$1,030	$111	$995	$11,980	$2,833	$49	$272,621 ($187/kW)

Source: Arthur D. Little, Inc., estimates.

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TABLE 17

DETAILED CAPITAL COST ESTIMATE

Plant Name: Powerton
Plant Location: Tazewell County, Illinois
Utility Name: Commonwealth Edison Company
Nameplate Generating Capacity (MW): 1786

Basis: Late 1982 Estimates
ENR Index = 3931.11 (1913 = 100)
= 365.97 (1967 = 100)

Capital Costs (thousands of $)

		Area 5100	**Area 5200**	**Area 5300**	**Area 5400**	**Area 5500**		**Area 5600**		**Area 5700**	**Area 5800**	
	Air Pollution Control	**Fly Ash Handling and Processing (Dry)**	**Fly Ash Storage**	**Slag Handling and Processing (Wet)**	**Fly Ash Handling and Processing (Wet)**	**Fly Ash Transport (Dry)**	**Slag Transport (Dry)**	**Fly Ash Placement and Disposal**	**Slag Placement and Disposal**	**Slag Recycle Water System**	**Miscellaneous Wastes Handling and Transport**	**Total**
Direct Costs												
Process Equipment		237	2,605	2,256	101	–	–	–	–	53	92	5,344
Piping and Insulation		622	38	317	17	–	–	37	59	463	343	1,896
Foundations and Structures		11	62	80	10	–	–	87	137	32	561	980
Site Preparation and Earthwork		–	–	–	–	–	–	21,489	33,610	–	–	55,099
Electrical		98	418	488	–	–	–	–	–	230	207	1,441
Instrumentation		40	170	211	1	–	–	2	3	115	100	642
Buildings		–	–	–	–	–	–	–	–	–	–	–
Subtotal	19,860	1,008	3,293	3,352	129	–	–	21,615	33,809	893	1,303	85,262
Site Monitoring Wells	–	–	–	–	–	–	–	7	10	–	–	17
Reclamation	–	–	–	–	–	–	–	1,204	1,882	–	–	3,086
Services and Miscellaneous	–	20	66	67	3	–	–	432	676	18	26	1,308
Mobile Equipment	–	–	–	–	–	301	471	611	955	–	–	2,338
Total Direct Investment	19,860	1,028	3,359	3,419	132	301	471	23,869	37,332	911	1,329	92,011
Indirect Costs												
Contractors Overhead	1,986	154	504	513	20	–	–	–	–	137	199	3,513
Contractors Profit	397	52	168	171	7	–	–	–	–	46	66	907
Subtotal	22,243	1,234	4,031	4,103	159	301	471	23,869	37,332	1,094	1,594	96,431
Engineering Design & Supervision	1,112	123	403	410	16	–	–	–	–	109	159	2,332
Architect – Engineering Fee	445	62	202	205	8	–	–	–	–	55	80	1,057
Subtotal	23,800	1,419	4,636	4,718	183	301	471	23,869	37,332	1,258	1,833	99,820
Contingency	7,193	426	1,391	1,415	55	91	141	6,798	10,632	377	550	29,069
Total Fixed Investment	30,993	1,845	6,027	6,133	238	392	612	30,667	47,964	1,635	2,383	128,889
Startup and Modifications	175	5	–	–	–	–	–	–	–	–	1	181
Interest During Construction (excluded)	–	–	–	–	–	–	–	–	–	–	–	–
Total Depreciable Investment (excluded)	31,168	1,850	6,027	6,133	238	392	612	30,667	47,964	1,635	2,384	129,070
Other Costs												
Land	–	–	–	–	–	–	–	562	882	–	–	1,444
Working Capital (excluded)	–	–	–	–	–	–	–	–	–	–	–	–
Total Capital Investment	$31,168	$1,850	$6,027	$6,133	$238	$392	$612	$31,229	$48,846	$1,635	$2,384	$130,514 ($73/kW)

Source: Arthur D. Little, Inc., estimates.

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TABLE . 18

DETAILED CAPITAL COST ESTIMATE

Plant Name: Smith
Plant Location: Bay County, Florida
Utility Name: Gulf Power Company
Nameplate Generating Capacity (MW): 340

Basis: Late 1982 Estimates
ENR Index = 3931.11 (1913 = 100)
= 365.97 (1967 = 100)

	Capital Costs (thousands of $)											
		Area 6100		Area 6200		Area 6300	Area 6400	Area 6500		Area 6600		
	Air Pollution Control	Fly Ash Transport	Fly Ash Handling and Processing	Bottom Ash Transport	Bottom Ash Handling and Processing	Coal Pile Runoff Handling and Transport	Miscellaneous Plant Waste Handling and Transport	Fly Ash Placement and Disposal	Bottom Ash Placement and Disposal	Fly Ash Recycle Water System	Bottom Ash Recycle Water System	Total
Direct Costs												
Process Equipment	–	126	64	56	99	16	48	–	–	32	4	445
Piping and Insulation	–	717	367	117	208	594	590	5	1	85	9	2,693
Foundations and Structures	–	3	1	1	3	19	17	–	–	128	14	186
Site Preparation and Earthwork	–	–	–	–	–	–	–	3,656	406	–	–	4,062
Electrical	–	122	63	93	166	140	144	–	–	131	15	874
Instrumentation	–	61	31	40	71	63	68	1	–	57	6	398
Buildings	–	–	–	–	–	–	–	–	–	–	–	–
Subtotal	21,179	1,029	526	307	547	832	867	3,662	407	433	48	29,837
Site Monitoring Wells	–	–	–	–	–	–	–	15	2	–	–	17
Reclamation	–	–	–	–	–	–	–	1,869	208	–	–	2,077
Services and Miscellaneous	–	20	11	6	11	17	17	73	8	9	1	173
Mobile Equipment	–	–	–	–	–	–	–	–	–	–	–	–
Total Direct Investment	21,179	1,049	537	313	558	849	884	5,619	625	442	49	32,104
Indirect Costs												
Contractors Overhead	2,118	157	81	47	84	128	133	560	62	67	7	3,444
Contractors Profit	423	52	27	15	28	42	44	187	21	23	2	864
Subtotal	23,720	1,258	645	375	670	1,019	1,061	6,366	708	532	58	36,412
Engineering Design and Supervision	1,186	126	65	37	67	102	106	448	50	53	6	2,246
Architect-Engineering Fee	474	63	32	19	33	50	53	224	25	27	3	1,003
Subtotal	25,380	1,447	742	431	770	1,171	1,220	7,038	783	612	67	39,661
Contingency	7,643	435	222	129	232	351	367	1,546	172	183	21	11,301
Total Fixed Investment	33,023	1,882	964	560	1,002	1,522	1,587	8,584	955	795	88	50,962
Startup and Modifications	99	–	–	–	–	–	–	–	–	–	–	99
Interest During Construction (excluded)	–	–	–	–	–	–	–	–	–	–	–	–
Total Depreciable Investment	33,122	1,882	964	560	1,002	1,522	1,587	8,584	955	795	88	51,061
Other Costs												
Land	–	–	–	–	–	–	–	892	97	–	–	989
Working Capital (excluded)	–	–	–	–	–	–	–	–	–	–	–	–
Total Capital Investment	$33,122	$1,882	$964	$560	$1,002	$1,522	$1,587	$9,476	$1,052	$795	$88	$52,050 ($153/kW)

Source: Arthur D. Little, Inc., estimates.

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TABLE 19

Plant Name: Allen
Plant Location: Gaston County, North Carolina
Utility Name: Duke Power Company

DETAILED OPERATING COST ESTIMATE

Operating Load Factor (%): 70
Nameplate Generating Capacity (MW): 1155
Waste Generation (dry metric tons/yr):
Fly Ash 275,900
Bottom Ash 102,000

	Operating Costs (thousands of $)								
	Area 1100	Area 1200	Area 1300		Area 1400	Area 1500	Area 1600		
	Fly Ash Handling and Processing	Bottom Ash Handling and Processing	Fly Ash Transport	Bottom Ash Transport	Coal Pile Runoff Transport	Miscellaneous Plant Waste Handling and Transport	Placement and Fly Ash Disposal	Placement and Bottom Ash Disposal	Total
Utilities									
Process Water	147.2	220.8	87.3	32.3	–	–	–	–	487.6
Electricity	95.0	296.6	99.2	36.7	76.1	53.1	–	–	656.7
Subtotal	242.2	517.4	186.5	69.0	76.1	53.1	–	–	1,144.3
Operating Labor									
Process Equipment Operator	84.1	36.0	18.0	6.0	4.0	4.0	6.0	2.0	160.1
Chemist	–	–	–	–	–	–	6.8	2.5	9.3
Foreman	7.2	3.1	1.5	0.6	0.3	0.3	0.5	0.2	13.7
Supervisor	7.8	3.4	1.6	0.7	0.4	0.4	0.5	0.2	15.0
Subtotal	99.1	42.5	21.1	7.3	4.7	4.7	13.8	4.9	198.1
Maintenance – (Material and Labor)									
Process Equipment Maintenance	149.8	56.7	315.3	116.6	37.1	39.3	0.5	0.2	715.5
Disposal Site Maintenance	–	–	–	–	–	–	339.3	125.5	464.8
Subtotal	149.8	56.7	315.3	116.6	37.1	39.3	339.8	125.7	1,180.3
Overhead									
General and Administrative Plant Overhead	170.7	60.3	216.3	80.0	25.0	26.3	195.0	72.2	845.8
Capital Charges	554.3	210.7	1,164.4	430.6	138.6	146.6	2,544.3	941.0	6,130.5
Subtotal	725.0	271.0	1,380.7	510.6	163.6	172.9	2,739.3	1,013.2	6,976.3
Total Operating Cost	$1,216.1	$887.6	$1,903.6	$703.5	$281.5	$270.0	$3,092.9	$1,143.8	$9,499.0 ($25.15/dry metric ton)

Basis: Late 1982 Estimates
ENR = 3931.11 (1913 = 100)
= 365.97 (1967 = 100)

Source: Arthur D. Little, Inc., estimates.

26476

TABLE 20

DETAILED OPERATING COST ESTIMATE

Plant Name: Elrama
Plant Location: Washington County, Pennsylvania
Utility Name: Duquesne Light Company

Operating Load Factor (%): 70
Nameplate Generating Capacity (MW): 520
Waste Generation (dry metric tons/yr):

Fly Ash	195,300
Bottom Ash	69,600
FGD Waste	135,300

Operating Costs (thousands of $)

	Area 2100	Area 2200	Area 2300	Area 2400	Area 2500	Area 2600	Area 2700		Area 2800			Area 2900			
	Fly Ash Handling and Processing (Dry)	Fly Ash Storage	Bottom Ash Handling and Processing (Wet)	Bottom Ash Transport (Wet)	Bottom Ash Interim Pond	Raw Material Handling and Storage	Fly Ash Handling and Processing (Wet)	FGD Waste Handling and Processing	Fly Ash Transport (Dry)	Bottom Ash Transport (Dry)	FGD Waste Transport (Dry)	Fly Ash Placement and Disposal	Bottom Ash Placement and Disposal	FGD Waste Placement and Disposal	Total
Raw Materials															
Lime	–	–	–	–	–	1,253.0	–	–	–	–	–	–	–	–	1,253.0
Utilities															
Process Water	95.0	0.1	168.6	–	–	–	–	–	–	–	–	–	–	–	263.7
Electricity	72.5	6.8	107.1	20.7	23.9	7.2	49.2	120.5	–	–	–	–	–	–	407.9
Fuel	–	–	–	–	–	–			137.4	47.7	95.2	22.6	7.9	15.7	326.5
Subtotal	167.5	6.9	275.7	20.7	23.9	7.2	49.2	120.5	137.4	47.7	95.2	22.6	7.9	15.7	998.1
Operating Labor															
Process Equipment Operator	72.1	24.0	20.9	10.5	3.5	109.8	95.5	234.0	–	–	–	–	–	–	570.3
Mobile Equipment Operator	–	–	–	–	–	–	–	–	267.5	92.8	185.7	51.0	17.7	35.3	650.0
Chemist	–	–	–	–	6.3			–	–	–	–	4.6	1.6	3.1	15.6
Foreman	4.9	1.7	1.5	0.7	0.3	27.3	23.7	58.2	–	–	–	12.7	4.4	8.9	144.3
Supervisor	9.9	3.2	2.9	1.5	0.5	7.5	6.5	16.0	–	–	–	14.7	5.1	10.2	78.0
Subtotal	86.9	28.9	25.3	12.7	10.6	144.6	125.7	308.2	267.5	92.8	185.7	83.0	28.8	57.5	1,458.2
Maintenance –															
(Materials & Labor)	49.2	119.2	53.4	92.8	95.8	27.8	151.4	370.8	359.7	124.8	249.6	108.5	37.6	75.2	1,915.8
Subcontracts															
Dredging	–	–	–	–	277.0	–	–	–	–	–	–	–	–	–	277.0
Overhead															
General and Administrative Plant Overhead	88.5	96.3	51.2	68.6	65.9	112.1	180.2	441.3	227.9	79.1	158.0	100.9	35.1	70.0	1,775.1
Capital Charges	180.8	438.4	196.3	341.3	468.3	102.5	558.7	1,367.9	342.1	118.7	237.4	501.7	174.0	348.1	5,376.2
Subtotal	269.3	534.7	247.5	409.9	534.2	214.6	738.9	1,809.2	570.0	197.8	359.4	602.6	209.1	418.1	7,151.3
Total Operating Cost	$572.9	$689.7	$601.9	$536.1	$941.5	$1,647.2	$1,065.2	$2,608.7	$1,334.6	$463.1	$925.9	$816.7	$283.4	$566.5	$13,053.4 ($32.60/dry metric ton)

Basis: Late 1982 Estimates
ENR = 3931.11 (1913 = 100)
365.97 (1967 = 100)

Source: Arthur D. Little, Inc., estimates.

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TABLE 21

DETAILED OPERATING COST ESTIMATE

Plant Name: Dave Johnston
Plant Location: Converse County, Wyoming
Utility Name: Pacific Power & Light Company

Operating Load Factor (%): 70
Nameplate Generating Capacity (MW): 420
Waste Generation (dry metric tons/yr): Fly Ash –153,000

	Operating Costs (thousands of $)				
	Area 3100	Area 3200	Area 3300	Area 3400	
	Fly Ash Handling and Processing	Fly Ash Storage	Fly Ash Transport	Fly Ash Placement and Disposal	Total
Utilities					
Process Water	–	1.0	–	1.3	2.3
Electricity	280.7	3.3	–	–	284.0
Fuel	–	–	28.3	30.5	58.8
Subtotal	280.7	4.3	28.3	31.8	345.1
Operating Labor					
Process Equipment Operator	48.1	8.0	22.9	–	79.0
Mobile Equipment Operator	–	–	19.5	39.0	58.5
Chemist	–	–	–	9.3	9.3
Foreman	15.1	2.5	12.6	10.8	41.0
Supervisor	4.1	0.7	3.5	3.0	11.3
Subtotal	67.3	11.2	58.5	62.1	199.1
Maintenance (Materials and Labor)					
Process Equipment Maintenance	276.0	104.5	–	0.7	381.2
Mobile Equipment Maintenance	–	–	48.8	54.1	102.9
Disposal Site Maintenance	–	–	–	97.0	97.0
Subtotal	276.0	104.5	48.8	151.8	581.1
Overhead					
General and Administrative Plant Overhead	222.9	75.2	45.4	112.0	455.5
Capital Charges	1,016.1	384.0	193.1	642.4	2,235.6
Subtotal	1,239.0	459.2	238.5	754.4	2,691.1
Total Operating Cost	**$1,863.0**	**$579.2**	**$374.1**	**$1,000.1**	**$3,816.4** ($24.90/dry metric ton)

Basis: Late 1982 Estimates
ENR = 3931.11 (1913 = 100)
= 365.97 (1967 = 100)

Source: Arthur D. Little, Inc., estimates.

26476

TABLE 22

DETAILED OPERATING COST ESTIMATE

Plant Name: Sherburne County
Plant Location: Sherburne County Minnesota
Utility Name: Northern States Power Company

Operating Load Factor (%): 70
Nameplate Generating Capacity (MW): 1468
Waste Generation (dry metric tons/yr):

Fly Ash	267,000
Bottom Ash	110,800
FGD Waste	103,900

Operating Costs (thousands of $)

	Area 4100		Area 4200		Area 4300		Area 4400		Area 4500	Area 4600	Area 4700	Area 4800	Area 4900	
	Fly Ash Handling and Processing	FGD Waste Handling and Processing	Fly Ash Transport	FGD Waste Transport	Fly Ash Placement and Disposal	FGD Waste Placement and Disposal	Fly Ash Recycle Water System	FGD Waste Recycle Water System	Bottom Ash Handling and Processing	Bottom Ash Transport	Bottom Ash Placement and Disposal	Bottom Ash Recycle Water System	Coal Pile Runoff and Plant Waste Handling and Transport	Total
Utilities														
Process Water	–	–	–	–	–	–	1.7	0.7	–	–	–	0.5	–	2.9
Electricity	51.8	20.2	16.0	6.2	–	–	99.0	38.5	–	–	–	73.5	–	305.2
Subtotal	51.8	20.2	16.0	6.2	–	–	100.7	39.2	–	–	–	74.0	–	308.1
Operating Labor														
Process Equipment Operator	103.8	40.4	8.6	3.4	4.3	1.7	17.3	6.7	72.1	24.0	6.0	12.0	4.0	304.3
Chemist	–	–	–	–	5.1	2.1	–	–	–	–	2.1	–	–	9.3
Foreman	9.2	3.6	0.8	0.3	0.4	0.2	1.6	0.6	6.6	2.2	0.6	1.1	0.3	27.5
Supervisor	5.1	2.0	0.4	0.2	0.2	0.1	0.9	0.3	3.6	1.2	0.3	0.6	0.1	15.0
Subtotal	118.1	46.0	9.8	3.9	10.0	4.1	19.8	7.6	82.3	27.4	9.0	13.7	4.4	356.1
Maintenance (Materials & Labor)														
Process Equipment Maintenance	413.8	160.9	46.2	18.0	0.4	0.1	105.9	41.2	4.4	39.8	0.2	115.3	2.0	948.2
Disposal Site Maintenance	–	–	–	–	383.4	149.1	–	–	–	–	262.2	–	–	794.7
Dredging	–	–	–	–	–	–	–	–	–	–	59.1	–	–	59.1
Subtotal	413.8	160.9	46.2	18.0	383.8	149.2	105.9	41.2	4.4	39.8	321.5	115.3	2.0	1,802.0
Overhead														
General & Administrative Overhead	345.7	134.6	36.4	14.2	255.8	99.7	81.7	31.7	56.4	43.7	176.5	83.7	4.2	1,364.2
Capital Charges	1,522.7	592.2	169.7	66.0	2,727.1	1,060.8	389.4	151.4	16.3	146.3	1,732.2	416.6	7.2	8,997.9
Subtotal	1,868.4	726.7	206.1	80.2	2,982.9	1,160.5	471.1	183.1	72.7	190.0	1,908.7	500.3	11.4	10,362.1
Total Operating Cost	$2,452.1	$953.8	$278.1	$108.3	$3,376.7	$1,313.8	$697.5	$271.1	$159.4	$257.2	$2,239.2	$703.3	$17.8	$12,828.3 ($26.60/dry metric ton)

Basis: Late 1982 Estimates
ENR = 3931.11 (1913 = 100)
= 365.97 (1967 = 100)

Source: Arthur D. Little, Inc., estimates.

26476

TABLE 23

DETAILED OPERATING COST ESTIMATE

Plant Name: Powerton
Plant Location: Tazewell County, Illinois
Utility Name: Commonwealth Edison Company

Operating Load Factor (%): 70
Nameplate Generating Capacity (MW): 1786
Waste Generation (dry metric tons/yr):
Fly Ash 300,000
Slag 472,800

Operating Costs (thousands of $)

	Area 5100	Area 5200	Area 5300	Area 5400	Area 5500		Area 5600		Area 5700	Area 5800	
	Fly Ash Handling and Processing (Dry)	Fly Ash Storage	Slag Handling and Processing (Wet)	Fly Ash Handling and Processing (Wet)	Fly Ash Transport (Dry)	Slag Transport (Dry)	Fly Ash Placement and Disposal	Slag Placement and Disposal	Slag Recycle Water System	Miscellaneous Wastes Handling and Transport	Total
Utilities											
Process Water	–	0.6	141.0	18.0	–	–	–	–	–	–	159.6
Electricity	36.1	15.3	109.9	3.7	–	–	–	–	12.4	0.3	177.7
Fuel	–	–	–	–	48.2	75.4	17.9	28.1	–	–	169.6
Subtotal	36.1	15.9	250.9	21.7	48.2	75.4	17.9	28.1	12.4	0.3	506.9
Operating Labor											
Process Equipment Operator	96.1	16.0	72.1	4.0	8.9	14.0	–	–	8.0	8.0	227.1
Mobile Equipment Operator	–	–	–	–	101.4	158.6	50.7	79.3	–	–	390.0
Chemist	–	–	–	–	–	–	3.6	5.7	–	–	9.3
Foreman	3.9	0.6	3.0	0.2	0.4	0.5	7.6	11.9	0.3	0.3	28.7
Supervisor	6.7	1.1	5.0	0.3	0.6	1.0	1.4	2.3	0.6	0.6	19.6
Subtotal	106.7	17.7	80.1	4.5	111.3	174.1	63.3	99.2	8.9	8.9	674.7
Maintenance – (Materials & Labor)	73.8	241.1	245.3	9.5	129.4	202.5	903.5	1,413.2	65.4	95.3	3,379.0
Overhead											
General and Administrative Overhead	117.3	168.2	211.5	9.1	91.8	143.5	606.8	949.1	48.3	67.7	2,413.3
Capital Charges	272.0	886.0	901.6	35.0	109.6	171.5	4,561.8	7,135.0	240.3	350.4	14,663.2
Subtotal	389.3	1,054.2	1,113.1	44.1	201.4	315.0	5,168.6	8,084.1	288.6	418.1	17,076.5
Total Operating Cost	$605.9	$1,328.9	$1,689.4	$79.8	$490.3	$767.0	$6,153.3	$9,624.6	$375.3	$522.6	$21,637.1 ($28.00/dry metric ton)

Basis: Late 1982 Estimates
ENR = 3931.11 (1913 = 100)
= 365.97 (1967 = 100)

Source: Arthur D. Little, Inc., estimates.

26476

TABLE 24

DETAILED OPERATING COST ESTIMATE

Plant Name: Smith
Plant Location: Bay County, Florida
Utility Name: Gulf Power Company

Operating Load Factor (%): 70
Nameplate Generating Capacity (MW): 340
Waste Generation (dry metric tons/yr):
Fly Ash 109,000
Bottom Ash 12,500

	Operating Costs (thousands of $)										
	Area 6100		Area 6200		Area 6300	Area 6400	Area 6500		Area 6600		
	Fly Ash Transport	Fly Ash Handling and Processing	Bottom Ash Transport	Bottom Ash Handling and Processing	Coal Pile Runoff Handling and Transport	Miscellaneous Plant Waste Handling and Transport	Fly Ash Placement and Disposal	Bottom Ash Placement and Disposal	Fly Ash Recycle Water System	Bottom Ash Recycle Water System	Total
Utilities											
Process Water	0.9	1.6	0.2	0.4	–	–	–	–	–	–	3.1
Electricity	41.9	81.4	6.2	10.9	2.9	7.7	–	–	18.5	2.1	171.6
Subtotal	42.8	83.0	6.4	11.3	2.9	7.7	–	–	18.5	2.1	174.7
Operating Labor											
Process Equipment Operator	12.2	23.8	8.6	15.4	4.0	4.0	7.2	0.8	10.8	1.2	88.0
Chemist	–	–	–	–	–	–	8.4	0.9	–	–	9.3
Foreman	1.9	3.7	1.3	2.4	0.6	0.6	1.1	0.1	1.7	0.2	13.6
Supervisor	2.1	4.0	1.4	2.6	0.7	0.7	1.3	0.1	1.9	0.2	15.0
Subtotal	16.2	31.5	11.3	20.4	5.3	5.3	18.0	1.9	14.4	1.6	125.9
Maintenance (Materials & Labor)											
Process Equipment Maintenance	38.7	75.1	22.5	40.0	60.9	63.5	0.6	0.1	31.8	3.5	336.7
Disposal Site	–	–	–	–	–	–	134.0	14.9	–	–	148.9
Subtotal	38.7	75.1	22.5	40.0	60.9	63.5	134.6	15.0	31.8	3.5	485.6
Overhead											
General and Administrative Plant Overhead	35.9	69.7	22.0	39.2	43.0	44.7	99.2	11.0	30.0	3.3	398.0
Capital Charges	142.3	276.1	82.7	146.9	223.7	233.3	1,183.5	131.5	116.8	13.0	2,549.8
Subtotal	178.2	345.8	104.7	186.1	266.7	278.0	1,282.7	142.5	146.8	16.3	2,947.8
Total Operating Cost	$275.9	$535.4	$144.9	$257.8	$336.8	$354.5	$1,435.3	$159.4	$211.5	$23.5	$3,734.0 ($30.75/dry metric ton)

Basis: Late 1982 Estimates
ENR = 3931.11 (1913 = 100)
= 365.97 (1967 = 100)

Source: Arthur D. Little, Inc., estimates.

APPENDIX H

ENVIRONMENTAL MATRIX EVALUATIONS

FULL-SCALE FIELD EVALUATION OF WASTE DISPOSAL FROM COAL-FIRED ELECTRIC GENERATING PLANTS

By

Chakra J. Santhanam
Armand A. Balasco
Itamar Bodek
Charles B. Cooper
John T. Humphrey (Haley & Aldrich, Inc.)
and
Barry K. Thacker (Bowser-Morner Testing Laboratories)

Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts 02140

EPA Contract 68-02-3167

EPA Project Officer: Julian W. Jones
Industrial Environmental Research Laboratory*
Office of Environmental Engineering and Technology
Research Triangle Park, North Carolina 27711

Prepared For

U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

(*) Now, Air and Energy Engineering Research Laboratory

APPENDIX H

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1 Introduction

Table 1, reproduced here from the main body of the report, presents a matrix of the sixty possible combinations of waste types, disposal methods and environmental settings that were considered in this study. In the subsequent section of this Exhibit, each matrix combination is discussed. The combinations are organized for discussion in accordance with the five categories of environmental settings.

TABLE [illegible].1

MATRIX SUMMARY OF INFORMATION AVAILABLE FOR COMBINATIONS OF WASTE TYPES, DISPOSAL METHODS, AND ENVIRONMENTAL SETTINGS

	Fly Ash[1]	Non-Fly Ash[2] Ba, FGD	Processed FGD	Dry FGD	Fly Ash[1]	Non-Fly Ash[2] Ba, FGD	Processed FGD	Dry FGD	Fly Ash[1]	Non-Fly Ash[2] Ba, FGD	Processed FGD	Dry FGD
COASTAL SETTING	X Smith	P	NA	NA	X/P[3] Chisman Cr. (USWAG)	P	P	NA	P	P	P	P[4]
ARID WESTERN SETTING- Not Highly Mineralized	P	P	NA	NA	P	P	P	NA	P	P	P	P[4]
ARID WESTERN SETTING - Highly Mineralized	P	P	NA	NA	P	P	P	NA	X Dave Johnston; North Dakota (DOE/EPA)	P	P	P[4]
INTERIOR SETTING - Not Highly Acidic	X Allen, Sherco, Michigan City (USWAG), Wallingford (USWAG)	P	X Bruce Mansfield	NA	X/P[3] Bailly (USWAG)	P	P	NA	X Powerton, Zuellinger (USWAG) Hunts Brook (USWAG) Dunkirk (DOE)	P	X Conesville (EPRI/USWAG)	P[4]
INTERIOR SETTING - Highly Acidic (mine drainage)	P	P	P	NA	P	P	P	NA	P	P	X Elrama	P[4]

Notes:
1. Includes co-disposal of fly ash with other wastes.
2. Includes FGD wastes without fly ash, and bottom ash.
3. Either the interim pond or landfill aspect of operation studied at field scale, but not both.
4. Lab data only.

Key:
X = Data available from full-scale field studies.
P = Data available from laboratory and/or limited-scale field studies for projection purposes.
NA = Matrix combination not applicable due to lack of present and future practice.

2 Combinations in Coastal Settings

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Pond Disposal, Coastal Setting

Summary of Effects Implications:

- A prevalent combination today, expected to remain important in future, especially with coal conversions(1).
- Leachate quality comparable in major species composition to tidally-influenced background waters(2)(3)(4).
- Leachate can have sufficiently elevated levels of leachable trace metals (e.g., As, Se) to be of concern in minority of cases(2)(5)(20).
- Heavy precipitation and pervious soils promote rapid leachate generation and movement(1)(4).
- Extensive admixing with tidally-influenced surface waters and near-surface aquifers mitigates against adverse impacts from major dissolved species; secondary drinking water standards are of little as no applicability in the receiving waters(4).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(6).
- In minority of cases where elevated concentrations of As or Se may prevail, mitigation may be achieved by selection of a site set in attenuative soil, or placement of such soil as a site liner.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash Waste (FGD, Bottom Ash), Pond Disposal, Coastal Setting

Summary of Effects Implications:

- Limited combination in practice today; some possible in future (1).
- Leachate quality comparable in major species composition to tidally-influenced background waters (2)(3)(4)(5)(6).
- Leachate can have sufficiently elevated levels of leachable trace metals (As, Se) to be of concern in minority of cases (5)(6).
- Heavy precipitation and pervious coastal soils promote rapid leachate generation and movement (1)(4).
- Extensive admixing with tidally-influenced surface waters and near-surface aquifers mitigates against adverse impacts from major dissolved species; secondary drinking water standards are of little or no applicability in the receiving waters (4).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types (1)(7).
- In minority of cases, where elevated concentrations of As or Se may prevail, mitigation may be achieved by selection of a site set in attenuative soil, or placement of such soil as a site liner.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Landfill Disposal, Coastal Setting

Summary of Effects Implications:

- Not presently prevalent, expected to become more prevalent in future(1).
- Leachate quality comparable in major species composition to tidally-influenced background waters(2)(3)(4)(15)(16).
- Leachate can have sufficiently elevated levels of leachable trace metals (e.g., As, Se) to be of concern in minority of cases(11)(13)(16).
- Heavy precipitation and pervious coastal soils promote rapid leachate generation and movement(1)(4)(7).
- Extensive admixing with tidally-influenced surface waters and near-surface aquifers mitigates against adverse impacts for major dissolved species; secondary drinking water standards of little or no applicability in the receiving water(4).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(7).
- In minority of cases, where elevated concentrations of As or Se may prevail, mitigation may be achieved by selection of a site set in attenuative soil, or by placement of such soil as a site liner.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Interim Pond-Landfill Disposal, Coastal Setting

Summary of Effects Implications:

- An uncommon but existing practice at present expected to be possible but not prevalent in future(1).
- Leachate quality comparable in major species composition to tidally-influenced background waters(2)(3)(4).
- Leachate from pond and landfill can have sufficiently elevated levels of leachable trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(6).
- Heavy precipitation and pervious soils promote rapid leachate generation and movement for both pond and landfill(1)(4)(6).
- Extensive admixing with tidally-influenced surface waters and near-surface aquifers mitigates against adverse impacts from major dissolved species; secondary drinking water standards are of little or no applicability in the receiving waters(4).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(6).
- In minority of cases where elevated concentrations of As or Se may prevail, mitigation may be achieved by selection of sites set in attenuative soil, or placement of such soil as site liners.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash (Bottom Ash, FGD) Waste, Interim Pond-Landfill Disposal, Coastal Setting

Summary of Effects Implications:

- An uncommon practice, expected to be possible but not prevalent in future (1).
- Leachate quality comparable in major species composition to tidally-influenced background waters (2)(3)(4)(5)(6).
- Leachate can have sufficiently elevated levels of leachable trace metals (As, Se) to be of concern in minority of cases (5)(6).
- Heavy precipitation and pervious coastal soils promote rapid leachate generation and movement for both pond and landfill (1)(4)(7).
- Extensive admixing with tidally-influenced surface waters and near-surface aquifers mitigates against adverse impacts from major dissolved species; secondary drinking water standards of little or no applicability in the receiving waters (4).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types (1)(7).
- In minority of cases, where elevated concentrations of As or Se may prevail, mitigation may be achieved by selection of a site set in attenuative soil, or placement of such soil as a site liner.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Interim Pond-Landfill Disposal, Coastal Setting

Summary of Effects Implications:

- Not presently practiced, expected to be possible but not likely in future(1).
- Leachate quality comparable in major species composition to tidally-influenced background waters(2)(3)(4)(5)(6)(8)(9)(10).
- Leachate can have sufficiently elevated levels of leachable trace metals (e.g., As, Se) to be of concern in minority of cases(5)(6)(8)(9)(10).
- Heavy precipitation and pervious coastal soils promote rapid leachate generation and movement for both pond and landfill(1)(4)(7).
- Extensive admixing with tidally-influenced surface waters and near-surface aquifers mitigates against adverse impacts from major dissolved species; secondary drinking water standards of little or no applicability in the receiving waters(4).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(7).
- In minority of cases, where elevated concentrations of As or Se may prevail, mitigation may be achieved by selection of a site set in attenuative soil, or by placement of such soil as a site liner.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash Waste (Bottom, Ash, FGD), Landfill Disposal, Coastal Setting

Summary of Effects Implications:

- Not presently prevalent, may exist in future (1).
- Leachate quality comparable in major species composition to tidally-influenced background waters (2)(3)(4)(5)(6)(10).
- Leachate can have sufficiently elevated levels of leachable trace metals (e.g., As, Se) to be of concern in minority of cases (2)(3)(5)(6)(10).
- Heavy precipitation and pervious coastal soils promote rapid leachate generation and movement (1)(4)(7).
- Extensive admixing with tidally-influenced surface waters and near-surface aquifers mitigates against adverse impacts for major dissolved species; secondary drinking water standards of little or no applicability in the receiving water (4).
- Chemical attenuation of trace metals in soils can be expected case-by-case on some, but not all, of the prevalent soil types (1)(7).
- In minority of cases, where elevated concentrations of As or Se may prevail, mitigation may be achieved by selection of a site set in attenuative soil, or by placement of such soil as a site liner.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Landfill Disposal, Coastal Setting

Summary of Effects Implications:

- Not presently practiced, may exist in future (1).
- Leachate quality comparable in major species composition to tidally-influenced background water (2)(3)(4)(5)(6)(8(9)(10).
- Leachate can have sufficiently elevated levels of leachable trace metals (e.g., As, Se) to be of concern in minority of cases (5)(6)(8)(9)(10).
- Heavy precipitation and pervious coastal soils promote rapid leachate generation and movement (1)(4)(7).
- Extensive admixing with tidally-influenced surface waters and near-surface aquifers mitigates against adverse impacts for major dissolved species; secondary drinking water standards of little or no applicability in the receiving water (4).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types (1)(7).
- In minority of cases, where elevated concentrations of As or Se may prevail, mitigation may be achieved by selection of a site set in attenuative soil, or by placement of such soil as a site liner.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Landfill Disposal, Coastal Setting

Summary of Effects Implications:

- Not presently practiced, may exist in future(1)(3).
- Leachate quality comparable in major species composition to tidally-influenced background waters(3)(25).
- Leachate can have sufficiently elevated levels of leachable trace metals to be of concern in minority of cases(25).
- Heavy precipitation and pervious coastal soils promote rapid leachate generation and movement(1)(4)(7).
- Extensive admixing with tidally-influenced surface waters and near-surface aquifers mitigates against adverse impacts for major dissolved species; secondary drinking water standards of little or no applicability in the receiving water(4).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(7).
- In minority of cases, where elevated concentrations of As or Se may prevail, mitigation may be achieved by selection of a site set in attenuative soil, or by placement of such soil as a site liner.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Interim Pond-Landfill Disposal, Coastal Setting

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of incongruity between production of dry FGD wastes and pond disposal.

Documentation: Not applicable.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Pond Disposal, Coastal Setting

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of incongruity between production of dry FGD wastes and pond disposal.

Documentation: Not applicable.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Pond Disposal, Coastal Setting

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of infeasibility of locating required size impoundments in coastal zone.

Documentation: Not applicable.

3 Combinations in Arid Settings: Not Highly Mineralized

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash, Pond Disposal, Arid Western Setting (not highly mineralized)

Summary of Effects Implications:

- Practice employed at present, expected to be less prevalent in future(1).
- Leachate can be expected to have sufficiently elevated levels of leachable major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards(2)(3)(11)(12)(13)(21).
- Leachate can have sufficiently elevated levels of leachable trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(11)(12)(13)(21).
- Pond head can promote leaching, but minimal precipitation, high net evaporation and general absence of significant near-surface groundwater generally reduce the opportunities for leachate generation and movement(1)(12).
- Opportunities for admixing also generally reduced by lack of water(1).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(11)(12).
- In extreme minority of cases, where elevated concentrations of major and/or minor leachate species could reach a small, immediately adjacent, usable surface water body or drinking water supply, mitigation may be achieved by selection of alternative disposal locations or lining of the disposal pond.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash (Bottom Ash, FGD), Pond Disposal, Arid Western Setting (not highly mineralized)

Summary of Effects Implications:

- Practice employed at present and expected in future (1).
- Leachate can be expected to have sufficiently elevated levels of leachable major species (e.g., sulfate, chloride) to be of potential concern with respect to secondary drinking water standards (2)(3)(11)(21).
- Leachate can have sufficiently elevated levels of leachable trace metals (e.g., As, Se) to be of concern in minority of cases (2)(3)(11)(21).
- Pond head can promote leaching, but minimal precipitation, high net evaporation and general absence of significant near-surface groundwater generally reduce the opportunities for leachate generation, movement and admixing (1)(12).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types (1)(11)(12).
- In the extreme minority of cases, where elevated concentrations of major and/or minor leachate species could reach a small, immediately adjacent, usable surface water body or drinking water supply, mitigation can be achieved by selection of alternative disposal locations or lining of the disposal pond.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Interim Pond-Landfill Disposal/Arid Western Setting (not highly mineralized)

Summary of Effects Implications:

- Practice employed at present, expected to be less prevalent in future(1).

- Leachate can be expected to have sufficiently elevated levels of leachable major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards(2)(3)(11)(12)(13)(21).

- Interim pond head can promote leaching, but minimal precipitation, high net evaporation and general absence of significant near-surface groundwater generally reduce the opportunities for leachate generation, movement and admixing, especially for the landfill(1)(12).

- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all of the prevalent soil types(1)(11)(12).

- In the extreme minority of cases, where elevated concentrations of major and/or minor leachate species could reach a small, usable surface water body or drinking water supply *immediately adjacent* to an interim pond, mitigation may be achieved by selection of alternative disposal location or lining of the disposal site.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash Waste (Bottom Ash, FGD Waste), Interim Pond-Landfill Disposal, Arid Western Setting (not highly mineralized)

Summary of Effects Implications:

- Practice employed at present, expected to be less prevalent in future(1).
- Leachate can be expected to have sufficiently elevated levels of leachable major species (e.g., sulfate, chloride) to be of potential concern with respect to secondary drinking water standards(2)(3)(11)(21).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(11)(21).
- Interim pond head can promote leaching, but minimal precipitation, high net evaporation and general absence of significant near-surface groundwater generally reduce the opportunities for leachate generation, movement and admixing(1)(2).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(11)(12).
- In the extreme minority of cases, where elevated concentrations of leachate species could reach a small, usable surface water body or drinking water supply immediately adjacent to an interim pond, mitigation can be achieved by selection of alternative disposal locations, or lining of the disposal site.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Interim Pond-Landfill Disposal, Arid Western Setting (not highly mineralized)

Summary of Effects Implications:

- Practice not employed at present, possible but not expected to be prevalent in future(1).
- Leachate can be expected to have sufficiently elevated levels of leachable major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards(2)(3)(5)(6)(8)(9)(10).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(5)(6)(8)(9)(10).
- Interim pond head can promote leaching, but minimal precipitation, high net evaporation and general absence of significant near-surface groundwater generally reduce to acceptable levels the opportunities for leachate generation, movement, and admixing(1)(12).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(11)(12).
- In the extremely rare case, where elevated concentrations of leachate species could reach a small, usable surface water body or drinking water supply immediately adjacent to an interim pond, mitigation can be achieved by selection of alternative disposal locations, or lining of the disposal site.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Landfill Disposal, Arid Western Setting (not highly mineralized)

Summary of Effects Implications:

- Presently important practice, expected to be prevalent in future(1).
- Leachate can be expected to have sufficiently elevated levels of leachable major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards(2)(3)(11)(12)(13).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(11)(12)(13).
- Combination of dry disposal method with minimal precipitation, high net evaporation, and general absence of significant near-surface groundwater reduces opportunities for leachate generation, movement and admixing to a minimum(1)(11)(12).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(11)(12).
- Opportunities for adverse impact are extremely rare, would be restricted to instances where landfill was actually developed in direct proximity to a usable drinking water supply. This circumstance could be mitigated by alternative disposal site selection or site lining.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash (Bottom Ash, FGD) Waste, Landfill Disposal, Arid Western Setting (not highly mineralized)

Summary of Effects Implications:

- Uncommon practice, expected to exist but not be prevalent in future(1).
- Leachate can be expected to have sufficiently elevated levels of leachable major species (e.g., sulfate, chloride) to be of potential concern with respect to secondary drinking water standards(2)(3)(5)(6)(11).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(5)(6)(11).
- Combination of dry disposal method with minimal precipitation, high net evaporation, and general absence of significant near-surface groundwater reduces opportunities for leachate generation, movement and admixing to a minimum(1)(11)(12).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(11)(12).
- Opportunities for adverse impact are extremely rare, would be restricted to instances where landfill was actually developed in direct proximity to a usable drinking water supply. This circumstance could be mitigated by alaternative disposal site selection or site lining.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Landfill Disposal, Arid Western Setting (not highly mineralized)

Summary fo Effects Implications:

- Not presently practiced, possible in future.

- Leachate can be expected to have sufficiently elevated levels of leachable major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards(2)(3)(5)(6)(8)(9)(10)(11).

- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(5)(6)(8)(9)(10)(11).

- Combination of dry disposal method with minimal precipitation, high net evaporation, and general absence of significant near-surface groundwater reduces opportunities for leachate generation, movement, and admixing to a minimum(1)(11)(12).

- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(11)(12).

- Opportunities for adverse impact are extremely rare, would be restricted to instances where landfill was actually developed in direct proximity to a usable drinking water supply. This circumstance could be mitigated by alternative disposal site selection or site lining.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Landfill Disposal, Arid Western Setting (not highly mineralized)

Summary of Effects Implications:

- Practice achieving commercialization, expected to become more prevalent in future(1)(3).
- Leachate can be expected to have sufficiently elevated levels of leachable major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards(3)(25).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(3)(25).
- Combination of dry disposal method with minimal precipitation, high net evaporation, and general absence of significant near-surface groundwater reduces opportunities for leachate generation, movement, and admixing to a minimum(1)(11)(12).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(11)(12).
- Opportunities for adverse impact are extremely rare, would be restricted to instances where landfill was actually developed in direct proximity to a usable drinking water supply. This circumstance could be mitigated by alternative disposal site selection or site lining.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Interim Pond-Landfill Disposal, Arid Western Setting (not highly mineralized)

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of incongruity between production of dry FGD wastes and pond disposal.

Documentation: Not applicable.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Pond Disposal, Arid Western Setting (not highly mineralized)

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of incongruity between production of dry FGD wastes and pond disposal.

Documentation: Not applicable.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Pond Disposal, Arid Western Setting (not highly mineralized)

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of impracticality of fulfilling the extraordinary water requirements in an arid setting.

Documentation: Not applicable.

4 Combinations in Arid Settings: Highly Mineralized

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Pond Disposal, Arid Western Setting (highly mineralized)

Summary of Effects Implicated:

- Practiced at present, expected to become less prevalent in future(1).
- Leachate quality comparable in major species composition to highly mineralized background waters(2)(3)(11)(12)(13)(21).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(11)(12)(13)(21).
- Pond head can promote leaching, but minimal precipitation, high net evaporation, and general absence of significant near-surface groundwater generally reduce the opportunities for leachate generation, movement, and admixing(1)(11)(12).
- Admixing with highly mineralized background waters effectively mitigates potential for adverse impacts of major leachate species on surface or groundwater(12).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(11)(12).
- Opportunities for adverse impact are extremely rare, would be restricted to instances where disposal area with extremely high leachable trace metal concentrations (e.g., As or Se) is actually developed in direct proximity to water used for other purposes (e.g., livestock, fisheries). This circumstance could be mitigated by alternative disposal site selection or site lining.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash Waste (Bottom Ash, FGD), Pond Disposal, Arid Western Setting (highly mineralized)

Summary of Effects Implications:

Same as for Fly Ash Waste, Pond Disposal, Arid Western Setting (highly mineralized), including same documentation.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Interim Pond-Landfill Disposal, Arid Western Setting (highly mineralized)

Summary of Effects Implications:

Same as for Fly Ash Waste, Pond Disposal, Arid Western Setting (highly mineralized), including same documentation.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash Waste, Interim Pond-Landfill Disposal, Arid Western Setting (highly mineralized)

Summary of Effects Implications:

- Practice possible but unlikely (1).
- Other points and references same as for Fly Ash Waste/Pond Disposal/Arid Western Setting (highly mineralized).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Interim Pond-Landfill Disposal, Arid Western Setting (highly mineralized)

Summary of Effects Implications:

- Not practiced at present, possible but unlikely in future(1).
- Leachate quality comparable in major species composition to highly mineralized background waters(2)(3)(5)(6)(8)(9)(10)(11)(12).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(5)(6)(8)(9)(10)(11)(12).
- Remaining points and references same as final four points for Fly Ash Waste, Pond Disposal, Arid Western Setting (highly mineralized).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Landfill Disposal, Arid Western Setting (highly mineralized)

Summary of Effects Implications:

- Important practice at present, expected to be more prevalent in future(1).
- Leachate quality comparable in major species composition to highly-mineralized background waters(2)(3)(11)(12)(13).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(11)(12)(13).
- Combination of dry disposal method with minimal precipitation, high net evaporation, and general absence of significant near-surface groundwater reduces opportunities for leachate generation, movement and admixing to a minimum(1)(11)(12).
- Admixing with highly mineralized background waters effectively mitigates remaining potential for adverse impacts of major leachate species on surface as groundwater(12).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(11)(12).
- Opportunities for adverse impact are extremely rare, would be restricted to instances where a landfill of wastes with extremely high levels of leachable trace metals (e.g., As, Se) was actually developed in direct proximity to water used for other purposes (e.g., livestock, fisheries). This circumstance could be mitigated by alternative disposal site selection or site lining.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash Waste (Bottom Ash, FGD), Landfill Disposal, Arid Western Setting (highly mineralized)

Summary of Effects Implications:

- Rare practice at present, expected to be possible but not prevalent in future (6).
- Remaining points and references same as for Fly Ash Waste, Landfill Disposal, Arid Western Setting (highly mineralized).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Landfill Disposal, Arid Western Setting (highly mineralized)

Summary of Effects Implications:

- Not practiced at present, possible in future (1).
- Leachate quality comparable in major species composition to highly mineralized background waters (2)(3)(5)(6)(8)(9)(10)(11)(12).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases (2)(3)(5)(6)(8)(9)(10)(11)(12).
- Remaining points and references the same as last 4 points for Fly Ash Waste, Landfill Disposal, Arid Western Setting (highly mineralized).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Landfill Disposal, Arid Western Setting
(highly mineralized)

Summary of Effects Implications:

- Presently in early stage of commercial practice, expected to be of future importance (1)(3).
- Leachate quality comparable in major species composition to highly mineralized background waters (5)(12)(25).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases (25).
- Remaining points and references same as final 4 points for Fly Ash Waste, Landfill Disposal, Arid Western Setting (highly mineralized).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Interim Pond-Landfill Disposal, Arid Western Setting (highly mineralized)

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of incongruity between production of dry FGD wastes and pond disposal.

Documentation: Not applicable.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Pond Disposal, Arid Western Setting (highly mineralized)

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of incongruity between production of dry FGD wastes and pond disposal.

Documentation: Not applicable.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Pond Disposal, Arid Western Setting (highly mineralized)

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of impracticality of fulfilling the extraordinary water requirements in an arid setting.

Documentation: Not applicable.

5 Combinations in Typical Interior Settings

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Pond Disposal Interior Setting (not highly acidic)

Summary of Effects Implications:

- Single most prevalent existing practice, expected to remain important(1).
- Leachate can be expected to have sufficiently elevated levels of major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards(2)(3)(13)(14)(16)(17)(21)(22).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(14)(16)(17)(19)(21)(22)(24).
- Pond head can promote leaching; typical range of interior climatic and hydrogeologic conditions can provide opportunities for waste leachates to effect measurable downgradient groundwater quality(1)(8)(13)(17)(19)(21)(22).
- Admixing with even small surface water bodies can have major dilution impact, mitigating potential leachate impacts on surface water and groundwater quality(13)(15)(17)(23).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all, of the prevalent soil types(1)(13)(17)(19)(21)(22).
- Opportunities for adverse impact would be expected in instances where disposal site is developed in pervious, non-attenuative soil in proximity to a useful groundwater supply; this circumstance could be mitigated by selection of a site set in relatively impermeable, chemically attenuative soil, or placement of such soil as a site liner.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash Waste (Bottom Ash, FGD), Pond Disposal, Interior Setting (not highly acidic)

Summary of Effects Implications:

- Common practice, expected to remain so in future (1).
- Leachate can be expected to have sufficiently elevated levels of major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards (2)(3)(5)(6)(10)(11)(21).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases (2)(3)(5)(6)(10)(11)(21).
- Remaining points and references some as final 4 points for Fly Ash Waste,

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Pond Disposal, Interior Setting (not highly acidic)

Summary of Effects Implications:

- Existing but rare practice, expected to remain so in future (1).
- Leachate can be expected to have sufficiently elevated levels of major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards (2)(3)(5)(18).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases (2)(3)(5).
- Size of ponds (can be greater than 1,000 acres) and high major species concentrations requires larger mixing volumes in receiving waters to achieve dilution by admixing comparable to that typical of other disposal combinations (18).
- Remaining points and references same as final 4 points for Fly Ash Waste, Pond Disposal, Interior Setting (not highly acidic).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Interim Pond-Landfill Disposal, Interior Setting (not highly acidic)

Summary of Effects Implications:

- Common practice at present, expected to be less prevalent in future (1).
- Remaining points and references same as final 6 points for Fly Ash Waste, Pond Disposal, Interior Setting (not highly acidic).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash Waste (Bottom Ash, FGD Waste), Interim Pond-Landfill Disposal, Interior Setting (not highly acidic)

Summary of Effects Implications:

- Common practice for bottom ash, rare for FGD waste; expected to become less prevalent in future(1).
- Leachate can be expected to have sufficiently elevated levels of major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards(2)(3)(5)(6)(10)(11)(21).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(5)(6)(10)(11)(21).
- Remaining points and references same as final 4 points for Fly Ash Waste, Pond Disposal, Interior Setting (not highly acidic).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Interim Pond-Landfill Disposal, Interior Setting (not highly acidic)

Summary of Effects Implications:

- Not presently practiced, unlikely but possible in future (1).
- Leachate can be expected to have sufficiently elevated levels of major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards (2)(3)(5).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases (2)(3)(5).
- Remaining points and references same as points 4, 6 and 7 for Fly Ash Waste, Pond Disposal, Interior Setting (not highly acidic).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Landfill Disposal, Interior Setting (not highly acidic)

Summary of Effects Implications:

- Important practice at present, expected to be more prevalent in future(1).
- Leachate can be expected to have sufficiently elevated levels of major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards(2)(3)(13)(14)(16)(17)(21)(22).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(13)(14)(16)(17)(19)(21)(22)(24).
- Dry disposal reduces volume and rate of leachate generation and movement; however, field studies confirm that typical range of interior climatic and geohydrologic conditions can provide opportunities for landfill leachate to effect measurably downgradient groundwater quality(1)(8)(9)(13)(14)(16)(17).
- Remaining three points and references same as for Fly Ash Waste, Pond Disposal, Interior Setting (not highly acidic).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash Waste (Bottom Ash, FGD), Landfill Disposal, Interior Setting (not highly acidic)

Summary of Effects Implications:

- Existing minority practice, expected to become more prevalent in future(1).
- Leachate can be expected to have sufficiently elevated levels of major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards(2)(3)(5)(6)(10)(11)(21).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(5)(6)(10)(11)(21).
- Dry disposal reduces volume and rate of leachate generation and movement; however, field studies confirm that typical range of interior climatic and geohydrologic conditions can provide opportunities for landfill leachate to effect measurably downgradient groundwater quality(1)(8)(9)(13)(14)(16)(17).
- Remaining points and references same as last 3 points for Fly Ash Waste, Pond Disposal, Interior Setting (not highly acidic).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Landfill Disposal, Interior Setting (not highly acidic)

Summary of Effects Implications:

- Practice recently initiated at several sites, expected to be significantly more prevalent in future(1).
- Leachate can be expected to have sufficiently elevated levels of major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards(2)(3)(5)(6)(8)(9)(10).
- Leachate can have sufficiently elevated levels of trace metals (e.g., As, Se) to be of concern in minority of cases(2)(3)(5)(6)(8)(9)(10).
- Dry disposal reduces volume and rate of leachate generation and movement; however, field studies confirm that typical range of interior climatic and hydrogeologic conditions can provide opportunities for landfill leachate to effect measurably downgradient groundwater quality(1)(8)(9)(13)(14)(16)(17).
- Remaining points and references same as last 3 points for Fly Ash Waste, Pond Disposal, Interior Setting (not highly acidic).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste Landfill Disposal, Interior Setting (not highly acidic)

Summary of Effects Implications:

- Practice in early stages of commercialization, expected to become more important in future (1) (3).
- Leachate can be expected to have sufficiently elevated levels of major species (e.g., sulfate) to be of potential concern with respect to secondary drinking water standards (3) (25).
- Leachate can have sufficiently elevated levels of trace metals (e.g., Se) to be of concern in minority of cases (25).
- Dry disposal method significantly reduces volume and rate of leachate generation and movement; however, field study results have shown that typical range of interior climatic and geohydrologic conditions provide opportunities for landfill leachate to effect measurably downgradient groundwater (1)(8)(9)(13)(14)(16).
- Remaining points and references same as final 3 points for Fly Ash Waste, Pond Disposal, Interior Setting (not highly acidic).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Pond Disposal, Interior Setting (not highly acidic)

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of incongruity between production of dry FGD wastes and pond disposal.

Documentation: Not applicable.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Interim Pond-Landfill Disposal, Interior Setting (not highly acidic)

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of incongruity between production of dry FGD wastes and ponding disposal.

Documentation: Not applicable.

6 Combinations in Interior Acid Mine Drainage Settings

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Pond Disposal, Interior Setting (acid mine drainage)

Summary of Effects Implications:

- Practice relatively uncommon, may continue to exist in future(1).
- Leachate quality comparable in major (and many minor) species composition (e.g., sulfate) to background waters affected by acid-mine drainage(2)(3)(8)(10)(14)(16)(17)(19)(21)(22)(23).
- Leachate can have sufficiently elevated levels of some trace metals (e.g., As) to be of concern in minority of cases(2)(3)(8)(10)(14)(16)(17)(19)(21)(22)(23).
- Pond head can promote leaching; typical range of interior climatic and hydrogeologic conditions can provide opportunities for waste leachates to effect measurably downgradient groundwater quality(1)(8)(13)(17)(19)(21)(22).
- Admixing with acid mine drainage in background waters mitigates against incremental adverse impacts from major dissolved species and several trace metals, secondary drinking water standards of limited applicability in receiving water(8).
- Admixing with even small surface water bodies can have major dilution impact on leachate, further mitigating potential leachate impacts on surface water and groundwater quality(8)(13)(15)(16)(23).
- Chemical attenuation of trace metals in soils can be expected case-by-case in some, but not all of the prevalent soil types(1)(13)(17)(19)(22).
- Opportunities for adverse impact would be rare, and are limited to situations in which leachate from a disposal area with extremely high leachable trace metal concentrations could reach and concentrate in a small water-body still used for such purposes as fishing in spite of prevalent acid mine drainage. Mitigation of this circumstance could be achieved by alternative disposal site selection or use of an appropriately attenuative soil as a site liner.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash Waste (Bottom Ash, FGD Waste), Pond Disposal, Interior Setting (acid mine drainage)

Summary of Effects Implications:

Same points and references as for Fly Ash Waste, Pond Disposal, Interior Setting (acid mine drainage).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Pond Disposal, Interior Setting (acid mine drainage)

Summary of Effects Implications:

- Uncommon practice presently restricted to Appalachian Region, where sites set in acid mine drainage may exist now or in future(1)(18).

- Leachate quality comparable in major (and many minor) species composition (e.g., sulfate) to background waters affected by acid mine drainage(2)(3)(5)(8)(18).

- Leachate can have sufficiently elevated levels of some trace metals (e.g., As, Se) to be of concern in minority of cases(2)(5).

- Size of ponds (can be greater than 1,000 acres) and high major species concentrations requires larger mixing volumes in receiving waters to achieve dilution by admixing comparable to that typical of other disposal combinations(18).

- Remaining points and references same as points 4, 5, 7 and 8 for Fly Ash Waste, Pond Disposal, Interior Setting (acid mine drainage).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Interim Pond-Landfill Disposal, Interior Setting (acid mine drainage)

Summary of Effects Implications:

Same points and references as for Fly Ash Waste, Pond Disposal, Interior Setting (acid mine drainage).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash Waste (Bottom Ash, FGD Waste), Interim Pond-Landfill Disposal, Interior Setting (acid mine drainage)

Summary of Effects Implications:

Same points and references as for Fly Ash Waste, Pond Disposal, Interior Setting (acid mine drainage).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Interim Pond-Landfill Disposal, Interior Setting (acid mine drainage)

Summary of Effects Implications:

- Not a present practice, possible but unlikely in future (1).
- Remaining points and references same as last seven points for Processed FGD Waste, Pond Disposal, Interior Setting (acid mine drainage), including by references points 4, 5, 7 and 8 for Fly Ash Waste, Pond Disposal, Interior Setting (acid mine drainage).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Fly Ash Waste, Landfill Disposal, Interior Setting (acid mine drainage)

Summary of Effects Implications:

- Existing practice in Appalachian Region, expected to continue in future(1).
- Dry disposal method significantly reduces volume and rate of leachate generation and movement; however, field study results have shown that typical range of interior climatic and geohydrologic conditions provide opportunities for landfill leachate to affect measurably downgradient groundwater quality(1)(8)(9)(13)(14)(16).
- Remaining points and references same as for points 2, 3, 5, 6, 7 and 8 for Fly Ash Waste, Pond Disposal, Interior Setting (acid mine drainage).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Non-Fly Ash Waste (Bottom Ash, FGD Waste), Landfill Disposal, Interior Setting (acid mine drainage)

Summary of Effects Implications:

- May be practiced for bottom ash in Appalachian Region at present, possible for bottom ash and/or FGD waste in future(1).
- Leachate quality comparable in major (and many minor) species composition to background waters affected by acid mine drainage(2)(3)(5)(6)(8)(10)(21).
- Leachate can have sufficiently elevated levels of some trace metals (e.g., Se) to be of concern in minority of cases(2)(3)(5)(6)(8)(10)(21).
- Dry disposal method significantly reduces volume and rate of leachate generation and movement; however, field study results have shown that typical range of interior climatic and geohydrologic conditions provide opportunities for landfill leachate to effect measurably downgradient groundwater quality(1)(8)(9)(13)(14)(16).
- Remaining points and references same as final four points for Fly Ash Waste, Pond Disposal, Interior Setting (acid mine drainage).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Processed FGD Waste, Landfill Disposal, Interior Setting (acid mine drainage)

Summary of Effects Implications:

- Existing practice in Appalachian Region, may occur with increased frequency in the future(1).
- Leachate quality comparable in major (and many minor) species composition (e.g., sulfate) to background waters affected by acid mine drainage(2)(3)(5)(6)(8)(9)(10).
- Leachate can have sufficiently elevated levels of some trace metals (e.g., As) to be of concern in minority of cases(2)(3)(5)(6)(8)(9)(10).
- Remaining points and references same as final two points for Non-Fly Ash Waste, Landfill Disposal, Interior Setting (acid mine drainage); including by reference final four points for Fly Ash Waste, Pond Disposal, Interior Setting (acid mine drainage).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Landfill Disposal, Interior Setting (acid mine drainage).

Summary of Effects Implications:

- Not a present practice; as technology is commercialized it is possible that this combination might be realized at a small number of sites effected by acid mine drainage(1)(3).
- Leachate quality comparable in major (and many minor) species composition to background waters affected by acid mine drainage(3)(25).
- Leachate can have sufficiently elevated levels of some trace metals (e.g., Se) to be of concern in minority of cases(3)(25).
- Remaining points and references same as final two points for Non-Fly Ash Waste, Landfill Disposal, Interior Setting (acid mine drainage); including by reference final four points for Fly Ash Waste Pond Disposal, Interior Setting (acid mine drainage).

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Pond Disposal, Interior Setting (highly acidic).

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of incongruity between production of dry FGD wastes and pond disposal.

Documentation: Not applicable.

MATRIX ASSESSMENT OF WASTE/DISPOSAL MODE/SETTING COMBINATIONS

Combination: Dry FGD Waste, Interim Pond-Landfill Disposal, Interior Setting (highly acidic)

Summary of Effects Implications:

Combination not presently applicable and not envisioned in future because of incongruity between production of dry FGD wastes and ponding disposal.

Documentation: Not applicable.

7 References

7 References

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APPENDIX I

QUALITY ASSURANCE/QUALITY CONTROL TESTING PROGRAM
PHYSICAL AND CHEMICAL SAMPLING AND ANALYSIS

By

Chakra J. Santhanam
Armand A. Balasco
Itamar Bodek
Charles B. Cooper
John T. Humphrey (Haley & Aldrich, Inc.)
and
Barry K. Thacker (Bowser-Morner Testing Laboratories)

Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts 02140

EPA Contract 68-02-3167

EPA Project Officer: Julian W. Jones
Industrial Environmental Research Laboratory*
Office of Environmental Engineering and Technology
Research Triangle Park, North Carolina 27711

Prepared For

U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

(*) Now, Air and Energy Engineering Research Laboratory

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1.0 PHYSICAL TESTING PROGRAM

1.1 PREPARATION AND APPROVAL OF WORK PLANS

1.1.1 Preparation of Procedures Manuals

Between December 1979 and July 1980, two procedures manuals were prepared for guidance in conducting the field and laboratory portions of the physical testing aspects of this program. The "Hydrologic and Geotechnical Procedures Manual," which gave guidance for field procedures, is designated as Appendix B. The "Sampling and Analysis Procedures Manual" specified laboratory procedures and is designated as Appendix C.

1.1.2 Inspection and Approval of Laboratory Facilities

Physical testing for this program was performed at Bowser-Morner Testing Laboratories, Dayton, Ohio. On December 19, 1979, before program samples were tested, D.J. Hagerty of the University of Louisville, a Quality Assurance (QA) Advisor, conducted a detailed inspection of the Bowser-Morner laboratories and equipment and found them suitable for the forthcoming work. During the testing program, periodic visits to the Bowser-Morner laboratories were conducted by Barry Thacker of Geologic Associates, Inc., as part of his day-to-day QA oversight of the physical testing aspects of the program.

Additional testing of samples from the sites was performed at the Department of Civil Engineering of the University of Louisville to supplement the Bowser-Morner results. Thacker also visited these facilities periodically during the program.

1.1.3 Preparation and Review of Site Evaluation Plans

The physical sampling and analysis portions of the Site Evaluation Plan for each site were prepared by Bowser-Morner under the supervision of Geologic Associates and Arthur D. Little. The University of Louisville provided further QA review of these documents to Arthur D. Little. Each participating utility also reviewed and approved its site evaluation plan.

1.1.4 Procurement of Contract Drilling Services

Bowser-Morner Testing Labs conducted the drilling operations at the Allen, Elrama and Dave Johnston sites and were supervised by the Project Geologist and/or Project Manager from Haley and Aldrich, Inc. At the Sherburne County site, Bowser-Morner performed the drilling under the supervision of Hickock Associates, Inc. The Haley and Aldrich Project Manager, working closely with Arthur D. Little, secured contract drilling services at the Powerton and Smith sites and supervised the drilling activities in the field.

1.2 MEASUREMENT PROGRAM

1.2.1 Sample Collection and Chain of Custody

A Haley and Aldrich staff geologist supervised the collection and handling of samples for physical testing at all sites except Sherburne County to confirm that the activities were in accordance with the two Procedures Manuals and any other special procedures in the individual Site Evaluation Plans. The Haley and Aldrich Project Geologist/Project Manager visited the same five sites near the end of the site development activity to verify further that the samples were collected and recorded properly. At the Sherburne County site, these functions were performed by the staff of Hickock Associates.

Samples from the Allen, Elrama, and Sherburne County sites were delivered to the Bowser-Morner laboratories by the returning Bowser-Morner field team. The Dave Johnston, Powerton, and Smith samples were shipped to Bowser-Morner by the Haley and Aldrich field personnel. At Bowser-Morner, sample custody was the responsibility of Ms. Judy Costello.

Additional samples from the Allen, Elrama, and Sherburne County sites were delivered directly to the University of Louisville by the Bowser-Morner field team. Samples from the Dave Johnston, Powerton, and Smith sites were shipped to the University of Louisville by the Haley and Aldrich field representative. At the University of Louisville, C.R. Ullrich was responsible for the custody of the samples.

1.2.2 Assessment of Precision, Accuracy, Completeness, Representativeness and Comparability

1.2.2.1 Routine Measurements

The following types of routine measurements were performed in the physical testing aspects of the program:

- field permeability tests (various heads),
- particle size tests,
- specific gravity tests,
- moisture content determinations,
- unified soil classification tests,
- compaction tests,
- unconfined compression tests, and
- constant head permeability tests (laboratory).

The tests were all conducted according to the procedures outlined in the two Procedures Manuals referenced above and also according to the relevant protocols of the American Society for Testing and Materials (ASTM):

D422	Particle Size Analysis,
D854	Specific Gravity of Soil Solids,
D2487	Classification for Engineering Purposes,
D698	Standard Compaction Test,

- D2166 Unconfined Compression Test, and
- D2434 Constant Head Permeability Test.

The assessment of precision, accuracy, completeness, representativeness, and comparability of the physical testing was conducted in two phases. The initial phase occurred during the actual field or laboratory test and involved verifying that the test was conducted in accordance with the "Hydrogeologic and Geotechnical Procedures Manual" and the "Sampling and Analysis Procedures Manual." The second phase of assessment consisted of comparing the results of the individual tests with the entire data base.

During the first phase of assessment, QA/QC field personnel from Haley and Aldrich, Hickock Associates, and Geologic Associates selected test locations at each site that were representative of conditions across the site. They then supervised the specific field testing to verify that the tests were being conducted as specified in the procedures manuals. As long as the correct procedures were being followed, the testing was continued to completion. If a complication developed during a test, that test was aborted and a new test location was selected. For example, during many of the field permeability tests, flow was measured through an open hole formed within the strata in question. In cases where the hole collapsed before the test was completed, the data were voided and a new test was initiated at an adjacent location.

Similarly, in the laboratory, Bowser-Morner and University of Louisville personnel performed the physical testing under the supervision of their appropriate QC personnel. As long as the tests were conducted according to the procedures manuals, the testing was continued. Otherwise, the tests were aborted. A summary of the laboratory tests performed is shown in Table 1.

During the second phase of the assessment, the applicable data developed at each site was compiled as shown in Figure 1. Data from testing of nearly identical samples was generally accepted when the results fell within about 2 standard deviations from the mean. For the field permeability tests, this corresponds to an accuracy of about ½ order of magnitude. However, in most cases, the samples were not identical and more qualitative assessment was required.

For example, at the Allen site, samples recovered from Boring 3-1 were visually classified. The ash became coarser grained and more pervious with increasing depth. These visual classifications were later verified by the results of Unified Soil Classification Tests. As indicated in Figure 1, both field and laboratory permeability test results showed that the finer grained fly ash near the surface of the basin had a coefficient of permeability ranging between $1x10^{-4}$ and $1x10^{-5}$ cm/sec. The coefficient of permeability of the ash increased with depth to $9x10^{-3}$ cm/sec. at a depth of 20 feet beneath the surface of the basin. Because of the excellent agreement of results from classification tests and results from field and laboratory permeability tests, the data were considered accurate within the previously described bounds for nearly identical samples.

As an independent assessment of the precision, accuracy, completeness, representativeness, and comparability of data developed by the Bowser-Morner

TABLE 1

SUMMARY OF PHYSICAL LABORATORY TESTS

Site	Permeability Tests	Classification Tests	Proctor Tests	Moisture Content Determinations	Shear Strength Tests
Proposed Model Fill (F)	5	6	6	20	1
Proposed Model Pond (P)	1	15	-	40	-
Allen (P)	5	8	1	28	1
Elrama (F)	12	10	1	36	9
Dave Johnston (F)	8	7	1	44	-
Powerton (F)	8	21	1	41	1
Sherco (P)	8	6	-	24	1
Smith (P)	4	5	-	15	-
Total Planned*	18	63	18	180	3
Total Performed*	45	57	4	188	12

*Note: 282 total tests were planned and 306 total tests were actually performed.

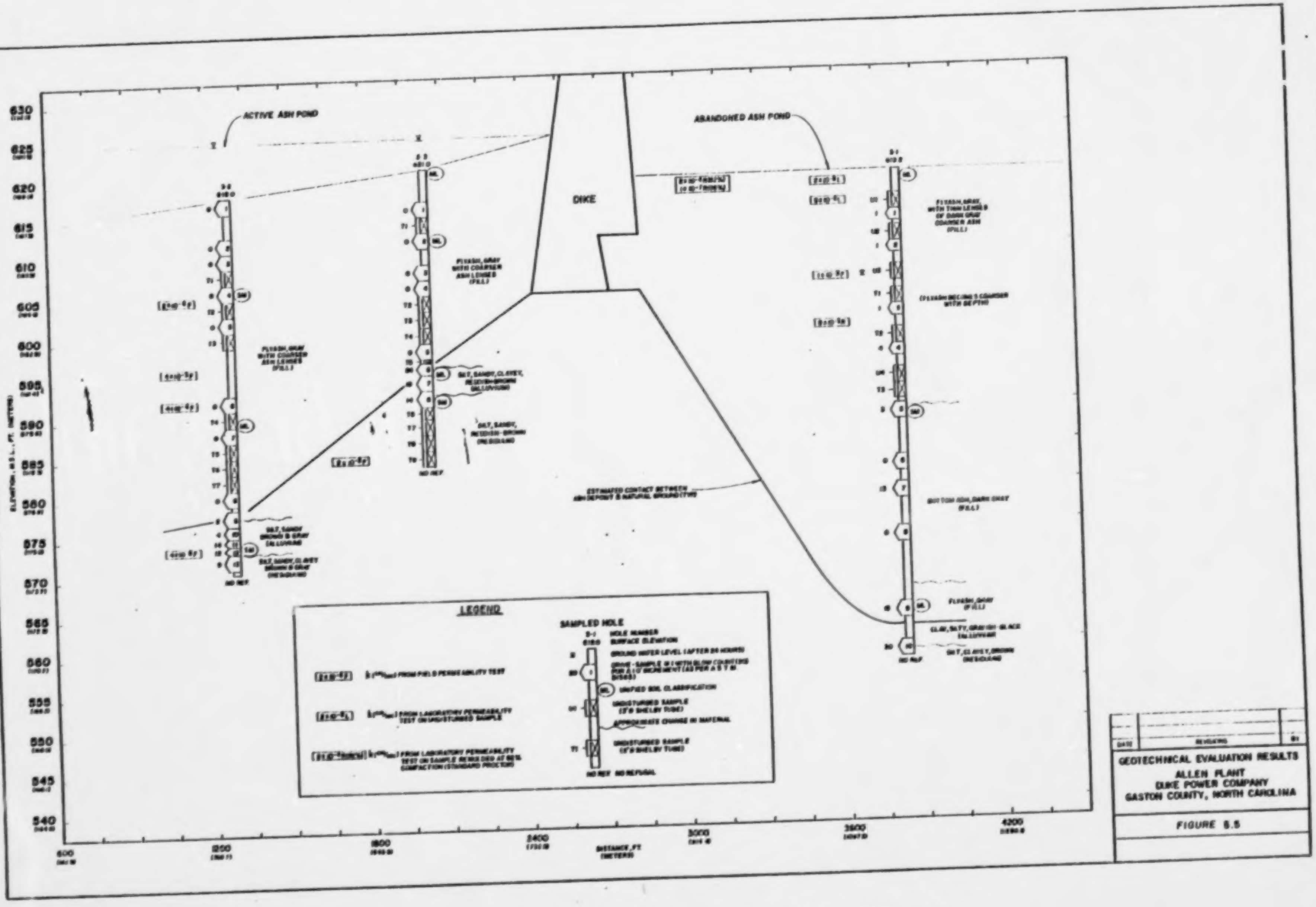
ACTIVE ASH POND
ABANDONED ASH POND
DIKE
FLYASH, GRAY WITH COARSER ASH LENSES (FILL)
SILT, SANDY, CLAYEY, REDDISH-BROWN (ALLUVIUM)
SILT, SANDY, REDDISH-BROWN (RESIDUUM)
SILT, SANDY BROWN & GRAY (ALLUVIUM)
SILT, SANDY, CLAYEY BROWN & GRAY (RESIDUUM)
FLYASH, GRAY WITH THIN LENSES OF DARK GRAY COARSER ASH (FILL)
(FLYASH BECOMES COARSER WITH DEPTH)
BOTTOM ASH, DARK GRAY (FILL)
FLYASH, GRAY (FILL)
CLAY, SILTY, GRAYISH-BLACK (ALLUVIUM)
SILT, CLAYEY, BROWN (RESIDUUM)
ESTIMATED CONTACT BETWEEN ASH DEPOSIT & NATURAL GROUND (TYP)
NO REF
ELEVATION, M.S.L., FT. (METERS)
630
625
620
615
610
605
600
595
590
585
580
575
570
565
560
555
550
545
540
600
1200
1800
2400
3000
3600
4200
DISTANCE, FT (METERS)
LEGEND
k FROM FIELD PERMEABILITY TEST
k FROM LABORATORY PERMEABILITY TEST ON UNDISTURBED SAMPLE
k FROM LABORATORY PERMEABILITY TEST ON SAMPLE REMOLDED AT 95% COMPACTION (STANDARD PROCTOR)
SAMPLED HOLE
HOLE NUMBER
SURFACE ELEVATION
GROUND WATER LEVEL (AFTER 24 HOURS)
UNIFIED SOIL CLASSIFICATION
UNDISTURBED SAMPLE
APPROXIMATE CHANGE IN MATERIAL
NO REF NO REFUSAL
DATE
REVISIONS
BY
GEOTECHNICAL EVALUATION RESULTS
ALLEN PLANT
DUKE POWER COMPANY
GASTON COUNTY, NORTH CAROLINA
FIGURE 5.5

FIGURE 1 GEOTECHNICAL EVALUATION RESULTS FROM THE ALLEN PLANT

laboratories, the QA/QC personnel reviewed the results of Bowser-Morner's participation in the American Association of State Highway and Transportation Officials (AASHTO) program for soils testing. This program (known as A.M.R.C.) consists of procedures generally identical to those approved by the ASTM, and, by agreement between AASHTO and ASTM, serves as the reference program for both organizations. On a scale of 0 to 5 (5 being the highest score), Bowser-Morner's scores in this program averaged higher than 4.5 for the 1980-83 period (i.e., their data was within 1.25 standard deviations of the mean).

As a result of this high score in the A.M.R.C. program and the favorable assessment by the QA/QC personnel during the testing laboratory, Bowser-Morner's results for the routine laboratory measurements performed in this program are considered within the generally accepted bounds of precision, accuracy, completeness, representativeness and comparability.

1.2.2.2 Non-Standard Measurements

Only one non-standard physical laboratory test, the extended permeability test, was performed in this program. At the time of testing, neither ASTM nor AASHTO had published a protocol or developed a refereed testing program for measuring the extended permeability of fine-grained, undisturbed samples. In late 1983, ASTM reportedly had such a protocol under development, and its specifications required the use of triaxial-type equipment and constant-head conditions, key features traditionally employed at Bowser-Morner that were also used in this program. The Bowser-Morner procedure was reviewed and approved by the QA Advisors from the University of Louisville before its use. They concluded that it represented a combination of the triaxial test apparatus approved by ASTM's standardized triaxial compression test and a permeability measurement procedure similar to that used in the ASTM-approved constant-head permeability test.

The data developed at Bowser-Morner was compared to data developed at the University of Louisville. As an example, Figure 2 shows a comparison of dry density to the log of the coefficient of permeability for samples of FGC waste recovered from the Sherburne County site. The comparison shows that the coefficient of permeability of the waste does not change at dry densities greater than about 78 pcf. However, the permeability drastically increases when its dry density falls below about 74 pcf. Such a relationship is common for fine grained cohesionless soil and would be expected from an FGC waste with similar grain size distribution.

Based on this and similar assessments, the QA/QC supervisors from Geologic Associates (who reviewed the results of each test) and the University of Louisville (who conducted reference tests of the same type on samples from the six sites) concluded that the results of Bowser-Morner's permeability tests were within the previously described bounds of precision, accuracy, completeness, representativeness and comparability (i.e., within 2 standard deviations of the mean for identical samples).

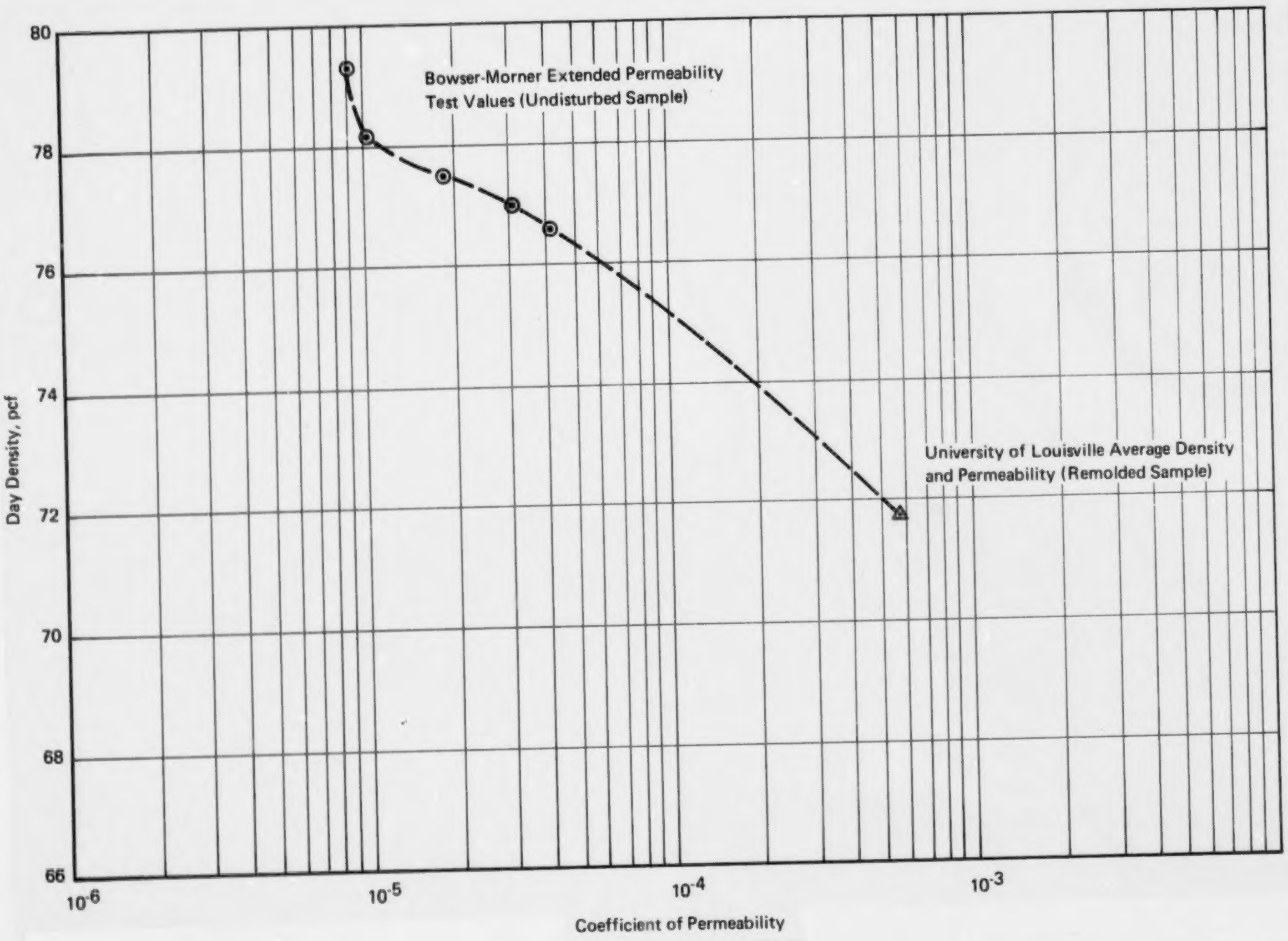

FIGURE 2 COMPARISON OF SHERBURNE COUNTY DATA FROM BOWSER-MORNER AND UNIVERSITY OF LOUISVILLE (COMPARABLE DEPTH AND MATERIAL)

1.3 LIMITATIONS ON USE OF THE DATA

There were no significant limitations on the use of the field and laboratory physical testing results. Questionable values were clearly flagged and had no effect on the continuing assessment. As previously described, the QA/QC program identified the tests where incorrect data were being generated. These tests were aborted. Excellent agreement between related data from various tests (i.e., field permeability tests, laboratory permeability tests, etc.) verified that the initial QA/QC screening process was successful in eliminating potential "outliers."

The physical testing data were considered along with other information in the overall assessment effort. Available information on waste permeability derived from field testing, extensive literature documentation, and results from the laboratory physical testing were used (along with other data) in four types of assessment activities:

- Development of site water balances.
- Evaluation of site cause-effect relationships.
- Projections of future conditions at the sites.
- Evaluation of the broader (industry-wide or generic implications of the disposal practices under study).

The following points show how the laboratory physical testing data were used in these assessment activities:

- In each of the three site-specific assessment activities, the physical testing data supplemented and supported both earlier field data (e.g., field permeability test results and water level measurements) and the evidence for leachate migration already provided by chemical correlations between in-waste and downgradient water samples.
- At each site where permeabilities at or greater than about 10^{-4} cm/sec were measured or anticipated (Allen, Dave Johnston, Powerton, and Smith), the chemical measurements appeared to provide early, relatively precise, and important "bottom line" indications of the history and importance of leachate movement over time. Thus, the chemical and physical testing results corroborated one another for the higher permeability waste deposits.
- When the rate of water movement through a waste deposit was important in the assessment calculations, the inherent uncertainty in both field and laboratory conditions was acknowledged by using boundary assumptions in the calculations. Invariably, there was less certainty and more need for assumptions with other parameters (e.g., liner thickness or permeability and stratigraphy of unmeasured, inhomogeneous natural soils) than the comparatively well-documented field and laboratory-measured waste permeabilities.

- The evaluation of the broader (industry-wide) implications of the disposal practices under study was partly based on the substantial body of permeability data from more than 15 field studies of full-scale sites and from many more laboratory studies. As discussed in Section 1.2.2.2, the Bowser-Morner and University of Louisville physical testing results were consistent with those of other investigations of similar wastes. The values for identical samples were within 2 standard deviations of the mean.

Examples of how the physical testing data were used in the assessment for each site are given below.

Allen Site

- The water balance was based on measurements made in the field before laboratory data were generated. As laboratory data became available, the results supported the assumptions used in the water balance.
- Chemical data from in-waste and downgradient wells provided the major basis for investigation of cause-effect relationships.
- The major assessment variables at this site were chemical attenuation of leachate trace metals in surrounding soils and the inhomogeneous nature of water movement patterns in the surrounding soils, not the waste deposit.

Elrama Site

- In the absence of field and laboratory data, the preliminary water balance was based on estimated hydraulic conductivities. When the laboratory permeability test data were available, they showed values within the expected range of variance from the original estimate. These laboratory data were then used in the revised water balance.
- The assessment of cause-effect relationships focused on the chemical interactions between contaminated acid-mine drainage and waste leachate at the site.

Dave Johnston Site

- The water balance was based on measurements made in the field before the laboratory data were generated. As laboratory data became available, the results supported the assumptions used in the water balance.
- Evaluation of cause-effect relationships focused on the extensive similarity of the leachate and the highly mineralized natural groundwater and on the minimal water movement in the relatively arid western setting.
- Future conditions were not projected for this site because of the minimal opportunities for incremental impacts.

Sherburne County Site

- The preliminary water balance was based on measurements made in the field before the laboratory physical testing data were generated. The laboratory data were consistent, within expectations, and provided a basis for calibrating the assessment without resolving the more important uncertainties over liner homogeneity (both composition and in thickness).

- Because of the inherent uncertainties in any attempt to characterize the inhomogeneities in the pond liner and the near-downgradient groundwater flow patterns at the site, the assessment of cause-effect relationships and future conditions relied primarily on chemical data, together with boundary assumptions governing the range of reasonable water movement possibilities at the site.

Powerton Site

- The water balance was based on measurements made in the field before the laboratory data had been generated. The laboratory physical testing data gave values in the expected range.

- The data on chemical quality of in-waste versus downgradient well concentrations of several waste-related chemicals provided early and clear "bottom-line" evidence of plume movement away from the waste deposit.

Smith Site

- The water balance was based on results of field measurements and results of the laboratory physical testing, which were in good agreement.

- The data on chemical quality of in-waste versus downgradient well and seep concentrations of two waste-related chemicals provided "bottom-line" evidence of plume movement consistent with the water balance.

1.4 RESULTS OF SYSTEMS AUDIT

On March 11, 1982, Alvia Gaskill, Jr., an environmental chemist from Research Triangle Institute (RTI) and Roy H. Borden, a civil engineer from North Carolina State University, Raleigh, North Carolina, who was serving as a consultant to RTI, visited Bowser-Morner Testing Laboratories to perform an audit of the physical testing activities under this program. The audit team and Bowser-Morner personnel participated in the audit visit.

The auditor's report* contained three summary conclusions. The first expressed a belief that there was no interaction between the University of Louisville and Bowser-Morner Laboratories, and that there were no QA audits during the program. The second was that field sampling, sample custody and shipping procedures, and laboratory facilities, equipment and procedures were acceptable with the exception of certain aspects of the permeability test apparatus. The final conclusion related to the second, was that the manner in which the permeability tests were conducted by Bowser-Morner could have led to erroneously low values.

After extensive investigation of the auditors' conclusions, the team responsible for this project concluded that:

1. The auditors had not accurately reflected the history of interaction between Bowser-Morner and the University of Louisville, and the extensive role of Geologic Associates in systematic QA oversight of the Bowser-Morner work.

2. The permeability test apparatus and its use reflected an appropriate combination of standardized test apparatus and procedures from other ASTM-approved procedures.

3. The Bowser-Morner and University of Louisville laboratory permeability test results and the field permeability tests results were generally in excellent agreement. Any differences accurately depicted the variations that were expected. See, for example, Figure 2 in Section 1.2.2.2.

4. None of the lower permeability values reported by Bowser-Morner had any major importance in the environmental assessment work for this project. As discussed in Section 1.3, chemical sampling and analysis results were available to document leachate movement and distribution downgradient at the sites where the lower permeabilities were obtained.

1.5 IDENTIFICATION AND RESOLUTION OF ANY SIGNIFICANT QA/QC PROBLEMS

No significant QA/QC problems remained unresolved in the physical testing aspects of this project. One problem thought to have some potential significance at the time was the discovery of some apparent corrosion of some Shelby-tube samples from the Elrama site. Sufficient uncorroded material was available to allow all the required analyses, and a protocol of frequent inspection and rapid processing of samples was initiated to avoid the potential for a similar problem at other sites. The problem did not recur with samples from any of the other sites.

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*"Systems Audit of Physical Testing Activities Performed for EPA Under Program for Characterization and Monitoring of Full Scale Utility Waste Disposal Sites" by Alvia Gaskill, Jr., RTI and Roy H. Borden, NCSU, EPA Contract No.: 68-02-3146, Task 184, EPA Project officer G.L. Johnson, Prepared for Technical Support Staff, EPA/IERL-RTP, North Carolina 27711, August 1982.

2.0 CHEMICAL SAMPLING AND ANALYSIS TESTING PROGRAM

2.1 OVERVIEW

Chemical sampling and analysis were conducted to:

- characterize the chemical concentrations of species of interest in waste solids, background soils, groundwater and surface water;
- identify potential waste-related chemical "tracers," i.e., those chemicals whose elevated concentrations in the waste and relative absence in background samples made them candidates for use in mapping the extent of waste-related contamination;
- map chemical concentration gradients to the waste deposits; and
- provide data to structure and test hypothesis to explain phenomena suspected to occur at the site (such as soil attenuation of trace metals).

2.2 PROGRAM PLANNING AND DOCUMENTATION

2.2.1 Preparation of Procedures Manual

An early activity in this program was to prepare a comprehensive set of procedure manuals that recommended and defined techniques that would be used during subsequent work. Among the documents prepared was a chemical sampling and analysis manual (Appendix C). This manual specified the types of analytical samples that would be collected and recommended procedures for how these samples would be collected and analyzed. It was intended to serve as a basis for all the chemical sampling and analysis activities.

2.2.2 Preparation and Review of Sampling Work Plans

Once the sample collection activities began, the recommended chemical analysis procedures were found to be appropriate and required no modification. However, time constraints and site-specific conditions required that several of the recommended sampling procedures be altered. To document these changes and control the amount of procedural variability that was introduced, a detailed sampling activities work plan was prepared before each field trip. This plan became the basis of all sampling activities. It was distributed among all members of the sampling crew, the chemical analysis quality assurance/quality control (QA/QC) overseer, the chemical analysis activities manager, and the overall program manager. This plan was also provided to the EPA Project Officer and to designated representatives of the participating electric utilities for their review.

The main purpose of this document was to state the objectives of each particular sampling activity and define how each scheduled field sampling and analysis activity was to be conducted. A second function was to provide an easy mechanism by which all sampling procedures could be monitored and so give program continuity between consecutive sampling trips to an individual disposal site as well as scheduled trips to all six disposal sites. This document also clearly identified and listed where and how many QA/QC samples were to be collected during each sampling trip.

2.2.3 Oversight of Contract Laboratories

During the program, TRW, Inc., served as a subcontractor for some facets of the sampling and analysis program. TRW performed IC analyses on field samples. Barringer Magenta, Inc., Toronto, Canada, performed ICAP analyses for metals on the samples obtained by both TRW and Arthur D. Little. Arthur D. Little supervised TRW's activities by reviewing sampling and analysis plans and by performing IC check analyses of selected TRW field samples.

The role of Barringer Magenta in the program was an important one, since they were responsible for generating the bulk of the analytical data. Before selection of Barringer Magenta, a set of qualification samples was submitted to them and to a competitor. Subsequently, the Arthur D. Little personnel responsible for chemical sampling and analysis and chemical QA/QC visited both organizations to inspect their laboratories and instrumentation and to evaluate their knowledge, capabilities and experience in performing ICAP analyses.

Blind QC samples were included with each lot of field samples submitted for ICAP analyses to monitor analytical performance. All samples submitted were identified only by a sample code number. The order of samples in each lot was intentionally randomized to make the identity of replicates less obvious. Throughout the program, Arthur D. Little personnel remained in close contact with Barringer Magenta. Whenever a potential problem in the ICAP data was discovered, Barringer Magenta was informed and Arthur D. Little personnel monitored their progress toward solving it. Barringer Magenta's cooperation throughout the program was excellent.

2.3 FIELD SAMPLING QUALITY ASSURANCE/QUALITY CONTROL

2.3.1 Sampling Protocols

With one exception, all the field sampling and analysis protocols used during this program were those that were initially defined in Appendix C. The exception was the manner in which samples of the groundwater in the saturated zone were obtained. The sampling methods are described below.

A. Waste and Soil Samples

Shelby tube and split-spoon sampling techniques were used during site development to obtain all waste and soil samples (including pond liner samples). The Shelby tube samples were shipped "as is" in tubes to the laboratory. The split-spoon samples were transferred to precleaned glass mason jars on-site and then shipped. Some waste samples were also collected during the subsequent sampling and analysis trips. These samples (mostly liquids and slurries) were obtained using grab sampling techniques. Wells were thoroughly flushed with in-situ water before grab sample collection, as required by the Procedures Manual.

B. Groundwater and Surface Water Samples

Samples were collected from groundwater monitoring points and several types of surface water sources. Sample types included saturated zone groundwater, samples from wells and piezometers, unsaturated zone groundwater samples from lysimeters, and samples of surface water (i.e., ponds, lakes, rivers, streams, swamps and tidal basins). Collected samples were split into two fractions, one for metal analysis and one for anion analysis. The metals fractions recovered were preserved with nitric acid as per pertinent DOT/EPA regulations, while the anion fractions were preserved by packing in ice. A comprehensive chain of custody record system adapted from NEIC (National Environmental Investigation Center) protocol was imposed on all field samples collected. Table 1 summarizes the sampling equipment used. Figure 3 is a schematic of the pneumatic pumping system used to sample groundwater.

C. Groundwater Well/Piezometer Sampling (Saturated Zone)

The intended procedure at the beginning of this project was to remove three to five well volumes before sample collection, as described in Appendix C. This proved impractical because of time limitations during sampling trips. The following procedure was developed instead. It saved time and provided the appropriate samples. In addition, the consistency of analyses results from trip to trip indicated the validity of this approach.

Any water above the screened section of a well was considered "stagnant" with respect to the "fresh" water located in the screened section (see Figure 3). This distinction is based on the fact that water can flow through the screened section and constantly replace water contained there. This new water has been more recently exposed to the geological formations outside the well casing. Water contained above the screened area is trapped, and its composition may change because of prolonged exposure to the atmosphere and to well casing materials. Therefore, the sample was withdrawn from below the fresh/stagnant water interface, with care to prevent any stagnant water from contaminating the sample. The following procedure was used:

1. Groundwater depth was measured to calculate the overall well volume and volume of stagnant water in the well (the well diameter was known). Before the sampling location was assessed, data were gathered as to the well diameter, screen volume (screen length times well cross-sectional area), screen/upriser interface depth, and overall well depth.

2. One well volume (overall well depth minus depth to water times well cross-sectional area) was removed from a location in the well that was as high above the fresh/stagnant water interface as possible. The fresh/stagnant water interface was assumed to coincide with the upper elevation of the screened section of the well. The point from which the initial well volume was removed was determined by the individual characteristics of each well, including factors such as well depth, groundwater depth, and the rate of well recharge. If the well did not recharge as quickly as the water was removed, the location of the sampling point was positioned at or just below the fresh/stagnant

TABLE 2

CHEMICAL SAMPLING EQUIPMENT

PUMPS:			
Peristaltic Pump	- Master flex portable sampling pump Horizon Ecology Co.		
Pneumatic Pump	- Designed and built at Arthur D. Little, Inc. The pump body consists of PVC pipe (1½", schedule 80 PVC), a check valve on the bottom to allow water to flow in, and a check valve at the top to prevent water from flowing back into the pump body once the pressure is released. Figure 1 shows the pump body along with the ancillary equipment needed for sample collection.		
INSTRUMENTS:			
pH Meters	- Horizon Ecology Co. (Type 5995) portable pH meter and a Beckman portable field (Model Monitor II System).		
Dissolved Oxygen Meter	- YSl Model 57 with built-in temperature probe.		
Conductivity Meter	- Chemtax, Inc., Type 70.		
FILTER HOLDER:	- Millipore 316 stainless sanitary XY3024236		
FILTERS:	- Millipore	0.45	HAWP14250
	- Millipore	prefilter	AW0614250
GRAB BUCKET:	- Polyethylene		
SAMPLE CONTAINERS:	- Polyethylene		
TUBING:	- All sampling lines in the wells were polyethylene tubing.		
	- Surface water samples were collected through Tygon® tubing.		
PNEUMATIC FLUID:	- Nitrogen		

Source: Arthur D. Little, Inc.

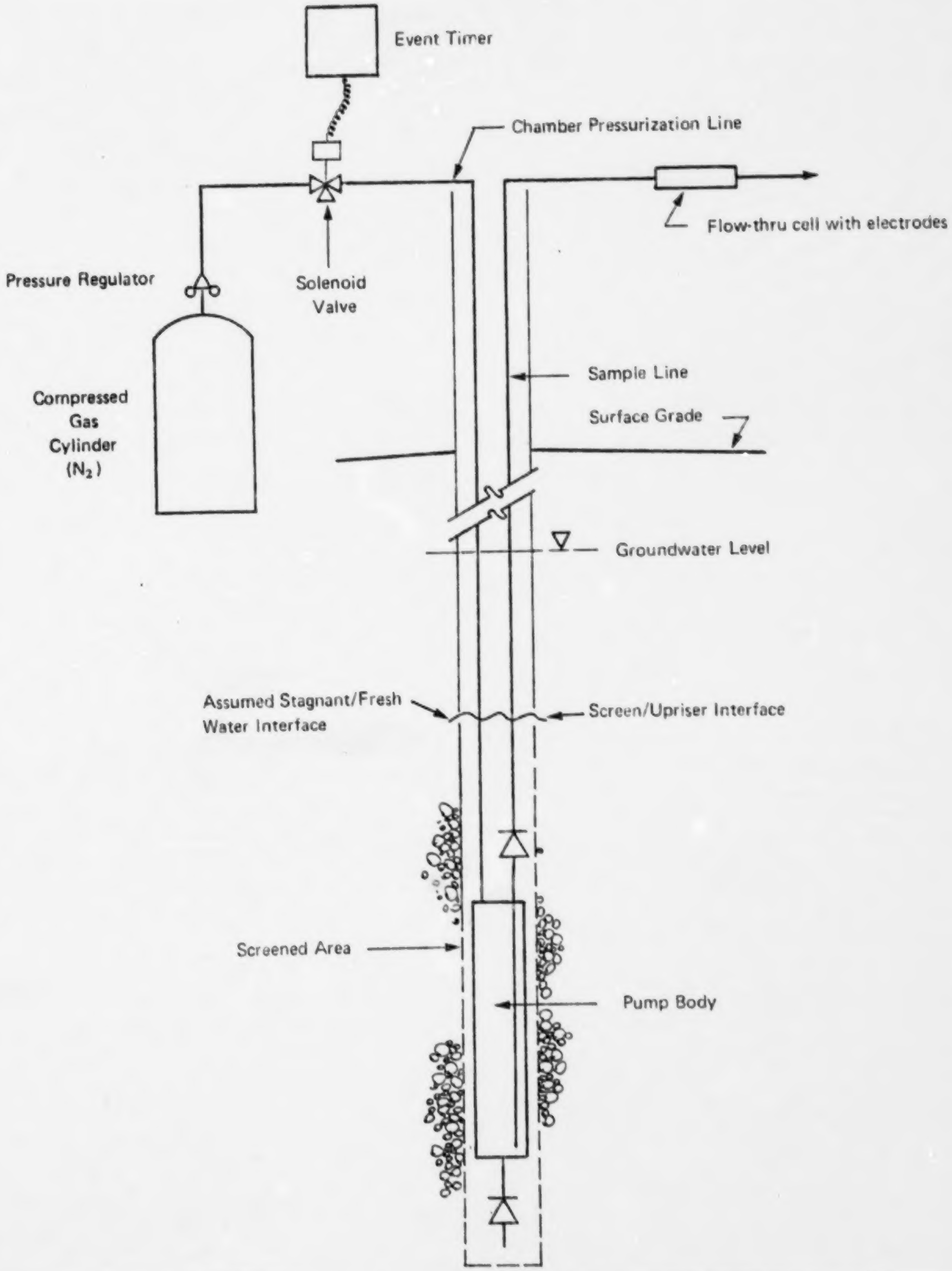


FIGURE 3 SCHEMATIC OF PNEUMATIC PUMPING SYSTEM

water interface. Once the stagnant water was removed, the sampling location was dropped to a point near the bottom of the screened section.

3. Successive screen volumes of water were removed from the bottom of the well and pumped through a flowthrough cell made from 2-inch acrylic tubing and electrodes to measure chemical parameters of the flowing water. Conductivity, pH, dissolved oxygen (D.O.), and temperatures were measured. Stabilization of these measurements indicated that the well water composition had reached equilibrium (minimal changes with successive pumping). When two consecutive parameter readings fell within the allowed tolerances (the allowed tolerances were pH ±0.3 units, conductivity ±10% relative; D.O. readings relatively consistent), the well was sampled.

This type of multilevel sampling approach greatly reduced the time required to sample each well by decreasing the volume of water that had to be removed before sample collection.

Two kinds of pumps served to evacuate the wells, pneumatic pumps and peristaltic pumps. The pneumatic pump was used when the water level in the well was below the suction lift capacity of the peristaltic pump. The pumping sequence and the volumes of water removed were the same for both types of pumps. One difference in procedure between the two pumps was that two separate tubes were placed in the well at the desired depths when the peristaltic pump was used. The peristaltic pump was connected to the appropriate tube to remove stagnant or fresh water. The pneumatic pump, however, was physically raised or lowered to locations above or below the screen/upriser interface to remove the desired type of water from the well.

Any exceptions to these procedures were fully documented in the field log of the sampling team, which was reviewed by the assessment team.

D. Lysimeter Sampling (Unsaturated Zone)

Lysimeters located in the unsaturated zone were sampled by a pressure-vacuum hand pump. The lysimeter was pressurized and evacuated of the accumulated standing water. A vacuum was applied to the lysimeter for six hours. The water collected in the lysimeter after this period was pumped into a container, and chemical parameters (pH, conductivity) were measured on a small aliquot of the unfiltered sample. The water was then filtered and preserved.

E. Surface Water Sampling

Surface water samples were collected with a peristaltic pump or a grab bucket. With the pump method, the pumping sequence applied was similar to the one used in sampling the groundwater wells. A volume of water (approximately 1000 mls) was pumped from the surface water source. Successive volumes (3500 mls) were then removed. Chemical parameters were measured (in the sampling stream) on each successive volume. A sample was taken after two consecutive parameter readings fell within the allowed tolerances. The sample volume was removed, filtered, split into anion and metal fractions, and preserved.

The grab bucket method was used at locations where it was impractical to collect surface water samples with the pump. In this approach, a volume of water was collected, and the sample was filtered, split and preserved. The excess unfiltered sample was used for measuring chemical parameters.

2.3.2 Field Quality Control Samples

Six types of quality control samples were usually collected during each field sampling visit. These were acid blanks, Milli Q® blanks, field blanks, other blanks, field duplicates, and sequential well or surface water duplicates, as described below:

- Acid Blanks - distilled and deionized water (Milli Q® water) containing the exact amount of nitric acid (HNO_3) used to stabilize samples for metal analysis. These samples were used for two determinations: (1) to provide a means of assessing whether precleaned sample bottles carried into the field became contaminated during the scheduled sampling activities; and (2) to determine if a particular lot of the preservation reagent used contained inordinate levels of undesirable contaminants. Assessing the quality of preservation reagent was considered extremely important because many lots of nitric acid had to be purchased and left at visited facilities due to shipping regulations imposed by the Department of Transportation.

- Milli Q® Blanks - distilled and deionized water (Milli Q® water) with no additives. These served as a blank for anion analyses and also provided a mechanism by which sample bottle contamination could be assessed independently of other possible field contaminant sources.

- Field Blanks - distilled water passed through the sampling devices (pneumatic pump, peristaltic pump, bailer and filtration apparatus) to check for equipment contamination. Aliquots were collected for both heavy metal and anion determinations.

- Other Blanks - samples of distilled water obtained at or near each of the visited test facilities. These samples had been used to rinse sampling equipment between successive applications. Aliquots collected for heavy metal and anion determinations were used to assess whether rinse water could have contributed any contamination.

- Field Duplicates - split of a field sample obtained from a well or a surface water location after all field collection activities (e.g., prebailing, parameter measurement, filtration but not sample preservation and packaging) had been completed. The split was taken immediately after the filtration step, and each sample aliquot was returned, preserved, and packaged as a unique field sample. These samples were shipped to the laboratory as blind replicates and used to assess precision of repetitive analysis of equivalent samples.

- Sequential Well or Surface Water Duplicates - equivalent but different volumes of sample water obtained from a monitoring well or a surface water sampling location. These samples were collected after one entire sample collection sequence had been completed at a sampling location and were treated as completely unique field samples. The data generated from the analysis of these samples were used to assess whether removing additional volumes of sample water caused any variability in the concentration of species found in samples. Table 2 lists all the field quality control samples obtained during this program.

2.3.3 Field Quality Control Procedures

In addition to the numerous quality control samples that were collected during each sampling trip, all field instrumentation used was routinely calibrated. Details of the standards used to calibrate and monitor the performance of field instrumentation are described below.

- Dissolved Oxygen. The response of the meter to humid air and to a sodium sulfite solution (D.O. = 0) was measured. This was performed at the beginning and end of each day's sampling.

- Conductivity. Standard potassium chloride (KCl) solutions (0.1, 0.029 and 0.001 N) were measured before and after sampling each day.

- pH. Buffers (pH 4, 7, 10) were checked at the beginning, end, and at least two other times during each sampling day.

- Temperature. Checks were made of the instrument with a mercury thermometer at the beginning and end of each sampling day.

2.3.4 Sample Documentation and Chain of Custody

A chain of custody record keeping system was used to track and control all samples that were collected during this program. This chain of custody system was based upon procedures recommended by the National Enforcement Investigation Center (NEIC) of the U.S. EPA which are outlined in the "NEIC Policies and Procedures Manual" (EPA-330/9/78/001-R).

Before any sampling was conducted, a field sample custodian and a laboratory sample custodian were identified. The role of this field sample custodian was to ensure that all samples were properly labeled, packaged, and maintained from the time of their collection until they were delivered to a common carrier for transport back to the analytical laboratory. The field sample custodian was also responsible for initiating the chain of custody record on all of the collected samples.

The laboratory custodian's role was to unpack samples upon receipt at the laboratory, inspect samples for obvious signs of tampering, and distribute samples for analysis. The laboratory custodian was also responsible for maintaining the chain of custody record.

TABLE 3

SUMMARY OF FIELD QUALITY CONTROL PROGRAM

Types of Samples	Plant 1 Elrama	Plant 3 Allen	Plant 5 Sherburne County	Plant 6 Powerton	Plant 7 Dave Johnson	Plant 9 Smith	Total
Blanks							
Field Blanks	7	7	5	6	2	10	37
Milli Q® or Distilled Water Blanks	9	7	6	4	2	5	33
Duplicates							
Field Duplicates	6	6	6	6	6	10	40
Sequential Duplicates	9	13	8	7	6	13	56
Laboratory	5	7	6	5	0	18	41
	—	—	—	—	—	—	—
	36	40	31	28	16	56	207

When samples were collected, they were immediately identified with a sample label. Solid samples obtained during site development activities were assigned numbers starting with an F and followed by a sequential four-digit number between 0000 and 9999. All groundwater, surface water, and solid samples obtained during subsequent sampling trips were identified with a label similar to the one shown in Figure 4.

As shown in Figure 4, the labels used to identify field samples contain five lines of preprinted information and space for the sampling personnel to write sampling date, name of collectors and comments. The key for the five lines of preprinted labeling information is explained below.

Contractor: ADL = Arthur D. Little, Inc.; TRW = TRW Systems, Inc.; Other = any other contractor collecting samples with name written in the comment section

Site Descriptor: 01 = Elrama
03 = Allen
05 = Sherburne County
06 = Powerton
07 = Dave Johnston
09 = Smith

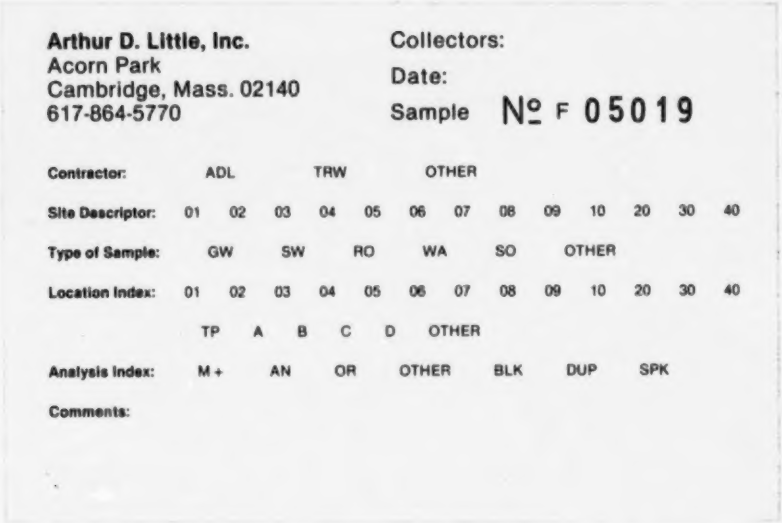
Type of Sample: GW = Groundwater; SW = Surface Water; RO = Runoff; WA = Waste; SO = Soil or Solid other than Waste; Other = All others (with description written)

Location Index: Sampling Location Number

Analysis Index: M+ = Metals; AN = Anionic Species, OR = Organic Species; Other = All other analyses; BLK = Blank with appropriate descriptor; DUP = Duplicate with appropriate descriptor; SPK = Spike

Once sample bottles had been filled and appropriately preserved, they were closed and sealed with a band of vinyl tape around the bottle cap and bottle neck. The sealed sample bottles were then placed into polyethylene bags which were sealed with signed chain of custody tags. These sealed bags were then individually packed into ice chests. When an ice chest was filled, the ice chest was closed, tagged with a signed and dated chain of custody tag, and sealed with fiberglass tape.

During the sample packing operation, label information from each bottle placed into the ice chest was recorded into a bound duplicating notebook. Entries made into the notebook included date of collection and packaging, sample location details, and analysis requested. This entry page was then signed and dated by the field custodian. The duplicate page was removed and attached to the sealed ice chest. This duplicate page served as a packing list for all shipments. When the packed samples were delivered to the common carrier (truck or air freight agent) for transport, the field sample custodian obtained a signed and dated copy of the bill of lading which became part of the chain of custody record.



Arthur D. Little, Inc.
Acorn Park
Cambridge, Mass. 02140
617-864-5770

Collectors:
Date:
Sample № F 05019

Contractor: ADL TRW OTHER

Site Descriptor: 01 02 03 04 05 06 07 08 09 10 20 30 40

Type of Sample: GW SW RO WA SO OTHER

Location Index: 01 02 03 04 05 06 07 08 09 10 20 30 40

TP A B C D OTHER

Analysis Index: M + AN OR OTHER BLK DUP SPK

Comments:

FIGURE 4 EXAMPLE OF SHIPPING LABEL

Upon receipt of the sample shipment in the laboratory, the laboratory sample custodian retrieved the packing lists and inspected the integrity of the chain of custody tag on each chest. The chests were then opened, and all samples were recovered. Each polyethylene bag was then opened and the sample bottle was recovered and inspected. The chain of custody tags attached to individual sample bottles were inspected for evidence of tampering.

Samples were checked for: 1) integrity of the seal placed on each bottle cap; 2) the presence of solid precipitates which sometimes formed during sample transport; and 3) pH (for the acidified samples). If a sample did not conform to the required condition, a remedial action was taken, such as adding nitric acid to dissolve solids or to lower the pH. Non-acidified samples containing particulates were filtered. Any manipulation of the samples was noted. If problems had been encountered with any field pH or conductivity equipment, a value for these parameters was obtained in the lab at this time.

The acidified water samples were then assigned "MF numbers" (MF for metals fraction), and the unacidified fraction of the same sample was assigned an "ICF number" (ICF for ion chromatography fraction). The ICF samples were stored in the refrigerator until analysis. Metal samples were stored at room temperature, as were soil samples and wastes. A list of sample numbers and a description of each sample were prepared for each batch of samples received (generally representing a particular sampling period for a particular site).

At this point, laboratory QC samples were prepared. These included laboratory splits, blind standards, and laboratory blanks. Liquid samples were then aliquoted into three plastic bottles (30 ml) and distributed as follows. A complete set of MF samples (including splits and blind standards) was sent to Barringer Magenta, Ltd. (Toronto, Canada) for inductively-coupled argon plasma (ICAP) analysis. These samples were prepared for shipment by the laboratory custodian, and these samples were transported under the same type of chain of custody procedures as described above. Another set was reserved for in-house metals analysis (As and Se) on selected samples. The third complete set of ICF samples was provided for in-house IC analysis.

Waste and soil samples were distributed after the site development boring logs had been reviewed and the particular samples designated for further chemical analysis had been identified.

2.4 LABORATORY ANALYSIS QUALITY ASSURANCE/QUALITY CONTROL

2.4.1 Analytical Protocols

All laboratory sample preparation and analysis protocols used during this program are defined in Appendix C. Synopses of each technique are provided below.

2.4.1.1 Laboratory Sample Preparation

A. Liquid Samples

The ICAP and IC liquid samples required no preparation (other than dilution) before they were introduced to the ICAP spectrometer or ion chromatograph. Analyses of As and Se based on hydride evolution were performed on as-received and stabilized water samples. In cases where the presence of organics was suspected, e.g., extracts of soils, samples were digested with HNO_3 and $HClO_4$, as explained in Appendix C. A check on a cross section of groundwater samples from the various sites generally showed small differences between digested and undigested samples.

B. Solid Samples

Solid samples of wastes and soils were freeze-dried under vacuum before they were shipped for analysis. The analysis, performed by Barringer Magenta, Ltd., involved a "total" digestion of the solids with a mixture of $HF/HNO_3/HClO_4$ before ICAP analysis. Solid samples for As and Se analysis were digested with $HNO_3/HClO_4$ before the AA/hydride evolution analysis of the digest.

C. Pore Liquid Samples

Pore liquids were obtained from moist or saturated waste solid and soil samples by the pressing technique described in Appendix C. Waste solids and liner solid samples were pressed under N_2 to obtain samples of the liquid phase. The samples were then passed through a 0.45 μm filter. Portions of the liquid were then acidified for metals analysis, and a portion was cooled for anion analysis.

D. Extracts

In cases where the pressing technique did not produce any liquid for analysis, a water extract was obtained by mixing distilled water with the solid and agitating the slurry in a shaker for one hour. The extract was separated from the slurry by filtration through a 0.45 μm filter.

2.4.1.2 Laboratory Analyses

Table 3 lists the analytes of interest in this program. The laboratory analyses are described below.

A. Inductively Coupled Argon Plasma Spectroscopy

Inductively coupled argon plasma (ICAP) spectroscopy was performed by Barringer Magenta, Ltd. The ICAP unit was a model QA-137 Applied Research Laboratories spectrometer with a 1920 rulings/mm grating. Reciprocal linear dispersion detectors (0.48-0.52/mm, first order R300) from Hamamatsu Corp. were used. The plasma observation height was 16 mm above load coil, 4-mm vertical section. Sample uptake was 2.25 ml/min by a cross-flow pneumatic

TABLE 4

ANALYTES, ANALYTE NUMBER DESIGNATION, AND ABBREVIATIONS

Liquids

1	Fluoride	F
2	Chloride	CL
3	Nitrate	NO_3
4	Sulfate	SO_4
5	Phosphate	PO_4
6	Bromide	BR
7	Silver	AG
8	Aluminum	AL
9	Boron	B
10	Barium	BA
11	Beryllium	BE
12	Calcium	CA
13	Cadmium	CD
14	Cobolt	CO
15	Chromium	CR
16	Copper	CU
17	Iron	FE
18	Potassium	K
19	Magnesium	MG
20	Manganese	MN
21	Molybdenum	MO
22	Sodium	NA
23	Nickel	NI
24	Phosphorus	P
25	Lead	PB
26	Silicon	SI
27	Strontium	SR
28	Thorium	TH
29	Titanium	TI
30	Vanadium	V
31	Zinc	ZN
32	Zirconium	ZR
33	Arsenic	AS
34	Selenium	SE
37	pH Lab	pH-L
38	pH Field	pH-F
39	Conductivity Lab	C-L
40	Conductivity Field	C-F
41	Groundwater Level	GRW
42	Dissolved Oxygen	DO
57	Bromate	BrO
60	Lead Graphite Furnace	PB-GR

Solids

7	Silver	AG
8	Aluminum	AL
11	Beryllium	BE
12	Calcium	CA
13	Cadmium	CD
14	Cobolt	CO
15	Chromium	CR
16	Copper	CU
17	Iron	FE
18	Potassium	K
19	Magnesium	MG
20	Manganese	MN
21	Molybdenum	MO
22	Sodium	NA
23	Nickel	NI
24	Phosphorus	P
25	Lead	PB
27	Strontium	SR
28	Thorium	TH
29	Titanium	TI
30	Vanadium	V
31	Zinc	ZN
32	Zirconium	ZR
43	Arsenic	AS
44	Selenium	SE
45	TOS (Sulfite)	TOS
46	Sulfate	SO_4
47	pH-Slurry	pH
48	Acid Insolubles	AI
49	Solids (%)	% SOL
50	F (Extractable)	F
51	CL (")	Cl
52	NO_3 (")	NO_3
53	SO_4 (")	SO_4
54	CO_4 (")	CO_4
55	Alkalinity (OH)	OH

Source: Arthur D. Little, Inc.

nebulizer with Scot chamber. A Jarrel-Ash monochromator (1/2 M Ebert) and a R787 Hamamatsu Corp. photomultiplier were used. Generator output was 1600 W at 27.12 MHz.

The ICAP analysis was performed by aspirating the undiluted sample. This analysis provides emission data for trace components as well as major species (up to 1000 ppm). A computer-based program, which corrects for interelement spectral interferences, is used to quantify trace elements. The major species (>100 ppm) are quantitated by diluting the original sample and reanalyzing it. These reanalyzed values are then used as input concentrations for major species in the interelement computer program.

The following elements were analyzed simultaneously for liquid samples: Ag, Al, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Si, Sr, Th, Ti, V, Zn, Zr. In the case of solid samples that had been digested with a mixture containing HF, the ICAP reports did not contain data for B and Si, which are at least partially lost due to formation of volatile fluorides. Data for Ba also were not available because of erratic results, probably due to formation of insoluble sulfate.

B. Ion Chromatography

Ion chromatography (IC) was performed on liquid samples with a Dionex Model 10 ion chromatograph equipped with a Varian autoinjector (Model 805500). The anion analysis system consisted of a precolumn, anion separator column, and a suppressor column followed by conductivity detector. Conditions for performing the analysis with $NaHCO_3/Na_2CO_3$ eluent were as specified in the instrument operator manual. Appendix C provides further details.

Analytes quantitated were F^-, Cl^-, NO_3^-, and $SO_4^=$. Chromatograms were also reviewed for the presence of Br^- and $PO_4^\equiv$.

C. Atomic Absorption

Atomic absorption (AA) measurements were performed for As, Se and Pb. Arsenic and selenium were analyzed by Arthur D. Little, Inc. The method was to use the hydride evolution technique on a Perkin Elmer Model 503 spectrometer equipped with an Instrumentation Laboratory Model 440 atomic vapor accessory. The detailed procedure is described in Appendix C.

Atomic absorption was also used to quantitate Pb in various amples. This analysis was performed by Barringer Magenta, Ltd., as part of the "ICAP analysis" suite. The methodology was either flame AA (with a Varian Techtron Model AAS under conditions specified by EPA Method 239.1) or flameless AA (with a Varian Techtron Model 475 and a Perkin Elmer Model HGA 2100 furnace under conditions specified in EPA Method 239.2).

D. Other Analyses

Total Organic Carbon -- Total organic carbon in soils was determined by Barringer Magenta, Ltd., with a LECO induction furnace Model 521-000 used according to manufacturer specifications. Sulfurous acid was added to remove inorganic carbonate, and the sample was then dried. The dried sample was combusted under O_2, and the CO_2 produced was absorbed in KOH. The change in gas volume was measured volumetrically.

Silicon in Solids -- Silicon in soils was determined by $LiBO_3$ fusion, dissolution of the solid residue in 10% HNO_3, and determination of Si in the solution by ICAP analysis (performed by Barringer Magenta, Ltd.).

Bromate Analysis -- Bromate analysis of boiler cleaning samples was performed by adding an aliquot of the sample (5-25 ml) to 10 ml of 2N hydrochloric acid (HCl) and 5 ml of 0.5N potassium iodide (KI) solution, with a few drops of ammonium paramolybdate solution to catalyze the reaction. The iodine (I_2) produced was titrated with standardized sodium thiosulfate. Starch was the end point indicator.

Other Solid Waste Characterization -- Measurement of total oxidizable sulfur (S), sulfate (SO_4^{-2}), acid insolubles. slurry pH, and % solids were made on selected FGD solid waste samples, as described in Appendix C. Solid samples were freeze-dried to constant weight to determine % solids before other analyses were carried out.

2.5 SPECIAL LABORATORY STUDIES

2.5.1 Soil Attenuation Measurements

Soil samples from each site were analyzed to determine the extent of attenuation of certain major and trace elements. Two leachate solutions (from the Allen site and from the Sherburne County site) were contacted with nine different soils from the various sites. These two solutions were "spiked" with Cd^{+2}, CrO_4^{-2}, Cu^{+2}, Pb^{+2}, and SeO_2^{-2}. (Spiking, the addition of a substance in known concentrations to a solution, is used when the original concentrations may be below detection limits. The procedure establishes measurable baseline concentrations that can be observed for changes when samples are then added to the solution.) A constant volume of spiked solution (50 ml) was mixed with various amounts of as-received soil (0.05, 0.5, 5 and 25 g). The resultant slurries were mixed for 24 hours in a rotary shaker. The slurry was then passed through a 0.45-μm filter, and the aqueous phase was preserved by addition of nitric acid and analyzed for pH, As, Se, and a suite of metals via ICAP analysis. A few unacidified extracts were subjected to ion chromatography to determine anions present. Calculations of the amount of analyte sorbed (removed from solution) onto the soil were based on the difference in concentrations in the starting solution and the solution equilibrated with the soil. A t-test (90% confidence level) was performed to determine if this difference in solution concentrations was significant. More information is given in Appendix F.

2.5.2 Extraction Procedure and Radioactivity Measurements

Twenty-three waste samples (fly ash and FGD wastes) were obtained from 18 utilities and subjected to the EPA Extraction Procedure (EP). Samples were used as-received, without drying or grinding. About 100 g of sample were extracted at pH 5.0± 0.2 for 24 hours. The separated aqueous phase was stabilized with nitric acid and analyzed for Ag, As, Se, Hg, Cr, Cd, Pb, and Ba. As and Se were analyzed by hydride-evolution AA. Hg analysis was conducted with the cold vapor atomic absorption method. Graphite furnace AA techniques were used to analyze all other elements.

Radioactivity measurements were made on 34 waste samples (fly ash, bottom ash, FGD, and boiler slag wastes) from 18 utilities. Gamma-ray spectroscopy was applied to analyze these samples for radium-226. Gamma-ray energies in the 0 to 2 MeV were screened, and emitting nuclides were identified by the characteristic energies of the gamma rays. Several samples were analyzed for radium-228, thorium-228, potassium-40, uranium-238, total uranium and radon emanation.

Appendix D, Application of the EPA Extraction Procedure and Radioactivity Measurements to Coal-Fired Utility Wastes, provides further information on these experiments, including QA/QC data.

2.6 LABORATORY QUALITY CONTROL PROCEDURES

Laboratory QC activities included inserting "blind" quality control samples into each batch of samples to be analyzed. In addition to this level of QC, ICAP analyses performed by Barringer Magenta, Ltd., were subject to that organization's internal routine laboratory QC program.

The following quality control samples (in addition to the field QC samples) were generated in-house:

- Laboratory Duplicate - a split of the field duplicate sample was made upon receipt of samples in the laboratory.
- Blind Standards - a triplicate set of blind standards was inserted routinely into each batch of samples. For larger batches, two triplicate sets were included.
- Digestion Blanks - for samples requiring in-house digestion, a blank was carried along with each batch.
- Spiked Samples - known amounts of standard solutions were added to the various liquid matrices observed during the project.

Quality control procedures were also practiced by Barringer Magenta, Ltd., during their ICAP analyses. Every 10th sample in a batch represented a quality control check sample in the form of a blank, repeat, or certified standard. If the sample was digested before analysis (e.g., solids), reagent blanks, repeat digestions, and appropriate certified solid samples were run. In addition, a drift standard was run after every 10th sample to check instrument stability.

The reference standards used by Arthur D. Little, Inc. throughout this project for liquid samples were Environmental Resource Associates (ERA, Chicago, Illinois) water quality control samples from various lots (MINERALS WasteWatR^{tm}, HARDNESS WasteWatR^{tm}, DEMAND WasteWatR^{tm}, NUTRIENTS WasteWatR^{tm}, TRACE METALS WasteWatR^{tm}). In addition, National Bureau of Standards (NBS) Trace Elements in Water reference standard (1643a) was routinely used. High concentration standards of certain elements (e.g., Si) were prepared from atomic absorption standards (Fischer Scientific). Results are discussed in Section 2.7.3.2.

For solid samples, the reference standards were NBS fly ash (1633 and 1633a) as well as River Sediment (1645). Results are discussed in Section 2.7.3.3.

Table 4 lists the laboratory quality control samples analyzed during this program. These are not categorized according to each individual site since, in most cases, samples from a variety of locations were analyzed simultaneously by the analytical technique.

2.7 ANALYTICAL DATA REVIEW AND ASSESSMENT OF QUALITY

The quality of the analytical chemical data generated during the program was assessed at three points--immediately upon receipt, after incorporation into the on-line data base, and, finally, after all data had been received.

2.7.1 Initial Review of Raw Data

When the analytical report for a batch of samples was received, the results obtained for blind QC samples were inspected before the data were entered into the data base. Reference standards were usually submitted in triplicate. Reproducible, but low or high recoveries for one or a few particular analytes were occasionally observed, suggesting instrument or calculation problems which were then investigated and corrected. The samples were reanalyzed, if necessary. Occasionally results from one member of a set differed substantially from the other members. These were discussed with the ICAP services vendor. Problems with their computerized report generator were identified and corrected.

2.7.2 Review of Data Base Summary Reports

After the problems detected in the initial review had been corrected, the data were entered into the on-line data base developed for the program. A site report containing the new data along with all the data from preceding trips was then printed out.

At the same time, an updated QC site report was prepared which summarized the results for all QC samples--blank levels, recoveries of standards, reproducibility of replicates, and recovery of spikes--analyzed up to that time. Reasons for high blanks [criteria: greater than three times the detection limit (DL)], bad standard or spike recoveries (outside the criteria range of 100 ±25%) or poor replicate precision (criteria: less than 75% RSD) were noted, investigated, and corrected. The newest data for each sampling location were compared to the data obtained during previous sampling trips. Any substantial changes were noted and checked.

TABLE 5

SUMMARY OF LABORATORY QUALITY CONTROL PROGRAM

ICAP	
Blanks	70
Duplicates	137
Standards	117
Spikes	30
IC	
Blanks	70
Duplicates	137
Standards	78
Spikes	12
AA (As, Se)	
Blanks	14
Standards	31
Spikes	18
Solids	
Standards	9
Duplicates	10

Source: Arthur D. Little, Inc.

2.7.3 Retrospective Assessment of Overall Data Quality

After all analyses were complete, the entire QC data file developed during the program was analyzed for an estimate of the overall quality of the data. This analysis was based on the criteria described in the preceding paragraph. Results are discussed below.

2.7.3.1 Behavior of Blanks

A total of 75 blanks were analyzed by ICAP during the program. Only a relatively small percentage showed detectable levels of the analytes sought. Table 5 shows for each element the number of positive blanks that fell into each of three concentration ranges--great than DL but less than or equal to 3 DL, greater than 3 DL but less than or equal to 10 DL, and greater than 10 DL. Included in the table are the corresponding detection limits for each element. The detection limits for ICAP were taken as reported by Barringer-Magenta based on their own internal QC program. In some instances the ICAP detection limits for particular elements changed somewhat (by a factor of 2-5) during the course of the program due to degradation or improvement in instrument performance. In those cases, the highest reported detection limits are shown in the table.

With only a few exceptions, the percentage of positive blanks was very small, and these were at levels very close to the detection limit. Calcium and magnesium were two exceptions. They were quite ubiquitous, and their ICAP detection limits were low. The blank levels observed were not significant when compared to the actual levels measured in field samples. A number of high cobalt and iron blanks were observed primarily during the first two sampling visits to Plant 5 (Sherburne County). Their possible impact on the site data was noted for the assessment team. Similarly, high silicon blanks were observed in samples from Plant 9 (Smith)--particularly blank samples of the local demineralized water used to rinse equipment. Again, their presence was noted. In many instances, samples taken from upgradient, background wells showed levels considerably below levels observed in the few positive blanks at that site; thus there was no effect on the assessment.

The behavior of 70 IC blanks is shown in Table 6. In only three instances was a value greater than 3 DL observed.

2.7.3.2 Behavior of Replicates

As discussed earlier, three types of replicate groundwater samples were taken during the program--sequential duplicate samples from the same source, field splits of a particular sample, and lab splits of a sample. Since sequential samples taken from the same sampling point are the best indicators of overall sampling and analysis precision, the results of an analysis of sequential well duplicates in shown in Table 7. The summary includes all duplicate pairs in which one of the two measurements was greater than the detection limits. In cases where one of the two measurements was less than the detection limit, the detection limit value was substituted for the missing value. Because Barringer-Magenta tends to set conservative detection limits well above instrument noise levels, it was more appropriate to use the

TABLE 6

LEVELS OF POSITIVE ICAP BLANKS[a]

Element	Detection Limit (ppm)	Number of Blanks in Range		
		≥DL-3DL	>3DL-10DL	>10DL
Silver	0.01	5	0	0
Aluminum	0.05	0	0	0
Boron	0.02	6	2	0
Barium	0.01	4	1	0
Beryllium	0.0005	2	0	0
Calcium	0.05	22	12	5
Cadmium	0.1	0	0	0
Cobalt	0.05	8	1	3
Chromium	0.05	3	0	0
Copper	0.008	8	5	1
Iron	0.01	6	12	7
Potassium	1.0	12	0	0
Magnesium	0.01	18	9	6
Manganese	0.01	5	0	1
Molybdenum	0.3	2	0	0
Sodium	2.0	5	1	1
Nickel	0.05	4	0	0
Phosphorous	0.6	0	0	0
Lead	0.05	2	0	0
Silicon	0.05	4	3	5
Strontium	0.001	23	5	3
Thorium	0.05	6	2	0
Titanium	0.005	7	0	0
Vanadium	0.005	15	4	0
Zinc	0.05	1	2	0
Zirconium	0.05	3	0	0

---

[a] A total of 75 blanks were analyzed.

Source: Arthur D. Little, Inc.

TABLE 7

LEVELS OF POSITIVE IC BLANKS[a]

Anion	Detection Limit (ppm)	Number of Blanks in Range		
		≥DL-3DL	>3DL-10DL	>10DL
Fluoride	0.1	4	0	0
Chloride	0.5	5	1	0
Nitrate	0.5	3	1	0
Sulfate	2.0	6	1	0

---

[a] A total of 70 blanks were analyzed.

Source: Arthur D. Little, Inc.

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TABLE 8

ANALYTICAL PRECISION FOR DUPLICATE WELL SAMPLES

Element	Percent Relative Standard Deviation for Various Concentration Levels		
Silver	0.005 – 0.009[a] –[b] 0[c]		
Aluminum	0.01 – 0.22 25% 6	0.22 – 0.78 10% 14	0.78 – 42.8 20% 3
Boron	0.004 – 0.068 12% 16	0.068 – 0.854 10% 15	0.854 – 103 2.6% 15
Barium	0.005 – 0.22 7.8% 43		
Beryllium	0.0005 – 0.0075 0.5% 4		
Calcium	0.81 – 52 3.5% 14	52 – 118 1.7% 18	118 – 1840 3.1% 24
Cadmium	0.007 – 0.045 17% 19	0.045 – 0.2 24% 1	
Cobalt	0.05 – 0.115 3.6% 7		
Chromium	0.008 – 0.15 2.2% 9		

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TABLE 8 (continued)

ANALYTICAL PRECISION FOR DUPLICATE WELL SAMPLES

Element	Percent Relative Standard Deviation for Various Concentration Levels		
Copper	0.005 - 0.041[a] 10.5%[b] 17[c]		
Iron	0.01 - 0.105 22% 24	0.105 - 0.94 19% 6	0.94 - 101 20% 11
Potassium	1.0 - 1.5 7.9% 6	1.5 - 67.5 4.6% 30	67.5 - 596 3.9% 3
Magnesium	0.79 - 9.27 5.7% 17	9.27 - 191 2.1% 36	191 - 2040 10.7% 3
Manganese	0.01 - 0.085 16% 16	0.085 - 0.84 11% 9	0.84 - 30.4 12% 14
Molybdenum	1.2 - 2.25 4.9% 2		
Sodium	2 - 68 3.6% 34	68 - 183 2.1% 6	183 - 7280 2.2% 13
Nickel	0.01 - 0.125 10.5% 15	0.125 - 0.28 5.4% 11	
Phosphorous	0.5 - 3.5 2.6% 19		

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TABLE 8 (continued)

ANALYTICAL PRECISION FOR DUPLICATE WELL SAMPLES

Element	Percent Relative Standard Deviation for Various Concentration Levels		
Lead	0.05 - 1[a] 0%[b] 1[c]		
Silicon	0.05 - 0.82 29% 4	0.82 - 0 1.8 27% 3	1.8 - 30 4.5% 27
Strontium	0.007 - 63 4.0% 56		
Thorium	0.01 - 0.25 7.4% 23		
Titanium	0.005 - 0.0205 8.5% 6		
Vanadium	0.005 - 0.0905 12.4% 22		
Zinc	0.02 - 0.19 8% 18	0.19 - 0.485 33% 2	
Zirconium	0.02 - 0.085 12.5% 2		
Fluoride	0.1 - 0.5[a] 3.2%[b] 17[c]	0.5 - 1.45 14% 7	1.45 - 48 10% 7

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TABLE 8 (continued)

ANALYTICAL PRECISION FOR DUPLICATE WELL SAMPLES

Element	Percent Relative Standard Deviation for Various Concentration Levels		
Chloride	0.5 - 2.5 6.7% 4	2.5 - 7 14% 15	7 - 14,700 8.9% 35
Nitrate	0.5 - 2.45 8.8% 14	2.45 - 6.5 14% 9	6.5 - 1,580 11% 16
Sulfate	2 - 6.45 7.4% 5	6.45 - 27.5 7.8% 8	27.5 - 8,370 8.1% 33

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[a] Concentration ranges (ppm)

[b] Relative Standard Deviation

[c] Number of sample pairs compared

Source: Arthur D. Little, Inc.

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detection limit value for a less-than value than to use zero. In many of the entries shown in Table 7, reproducibilities have been calculated for two or three ranges of concentrations encountered during the program. For example, six pairs of aluminum duplicates ranging in concentration from 0.01 to 0.22 ppm were observed to have a relative standard deviation (RSD) of 25%. Fourteen aluminum samples in the range of 0.22 to 0.78 ppm had an RSD of 10% and three pairs ranging in concentration from 0.78 to 42.8 ppm had an RSD of 20%.

In general, reproducibility was quite good. Except for silicon and two pairs of zinc samples, all the RSD's were 25% or less, consistent with program goals.

2.7.3.3 Recoveries of Analytical Standards

Analytical standards at various concentrations were submitted blind with each set of samples for ICAP and IC. The recoveries of analytical standards observed throughout the program are summarized for one to three different concentration ranges in Tables 8 and 9. Listed beneath each concentration range is the average percent recovery followed by the standard deviation for that set of percent recoveries. Below the recovery data is shown the number of standards which comprised the set. Many of the results were within ±10% of the expected value; with only a few exceptions all were within ±25%. Aluminum measurements at the relatively low levels studied were scattered and on the average high. Cobalt and nickel recoveries at the lowest concentration range (less than 2 DL) were high and low, respectively. These observations for aluminum, cobalt, and nickel were communicated to the assessment team. In all cases, the assessment team was able to complete the required analysis without using questionable data. Lead standards at concentrations up to about five times the detection limit were erratic and low. To better quantitate lead at low concentrations, selected samples were analyzed by graphite furnace atomic absorption spectroscopy. Nitrate standards in the concentration range 0.5 to 2 ppm were also quite imprecise and the recoveries were high. Nitrate measurements at those concentration levels were not important in the assessment process.

2.7.3.4 Results of Spiking Experiments

Throughout the program, selected samples were spiked with known amounts of elements of particular interest. Spiking studies were most important in the samples obtained from Plant 9 (Smith), because many contained constituents of sea water at relatively high concentrations. The results of the spiking studies are tabulated in Attachment 1. For each element, the information in the first column at the left identifies the nature of the sample that was spiked. The next two columns to the right identify the concentration or range of concentrations added to the sample. The next column contains the number of samples spiked, followed by the average percent recovery for the spike, the standard deviation of those recoveries and finally, the percent relative standard deviation.

Most recoveries lay within the 75% to 125% recovery range. Aluminum, as noted above, was erratic and on the average high. Barium recovery from sea

TABLE 9

RECOVERIES OF ANALYTICAL REFERENCE STANDARDS FOR WATER SAMPLES

Element	Percent Recovery ± Standard Deviation for Various Concentration Levels		
Silver	0.05 - 0.1[a] 97 ± 8[b] 10[c]	0.1 - 0.2 100 ± 3 2	
Aluminum	0.24 - 0.96 166 ± 63 24		
Boron	0.1 - 0.9 93 ± 17 35	0.9 - 95 93 ± 1.8 5	
Barium	0.046 - 0.141 83 ± 12 21	0.141 - 2.64 94 ± 12 65	2.64 - 4.4 102 ± 6.5 3
Beryllium	0.019 - 0.099 90 ± 7.6 30	0.099 - 0.6 91 ± 8.1 57	0.6 - 1 100 ± 3.6 3
Calcium	52 - 118 99 ± 2.9 21	118 - 829 100 ± 6 21	
Cadmium	0.05 - 0.54 101 ± 42 65	0.54 - 0.9 89 ± 5 3	
Cobalt	0.082 - 0.096 131 ± 23 2	0.096 - 1.7 91 ± 39 65	1.7 - 2.55 101 ± 3 3
Chromium	0.017 - 0.08 117 ± 73 19	0.08 - 1.5 93 ± 17 56	1.5 - 2.5 110 ± 5.3 3

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TABLE 9 (continued)

RECOVERIES OF ANALYTICAL REFERENCE STANDARDS FOR WATER SAMPLES

Element	Percent Recovery ± Standard Deviation for Various Concentration Levels		
Copper	0.018 - 0.064 89 ± 38 25	0.064 - 1.2 97 ± 6.6 65	1.2 - 2.0 100 ± 2.0 3
Iron	0.078 - 0.109[a] 78 ± 39[b] 25[c]	0.109 - 2.0 106 ± 22 65	2.0 - 3.4 103 ± 3.3 3
Potassium	1.5 - 100 105 ± 22 32	100 - 591 106 ± 9.8 11	
Magnesium	10 - 200 102 ± 7.2 39	200 - 500 99 ± 4.0 3	
Manganese	0.031 - 0.0832 94 ± 6 22	0.0832 - 1.56 101 ± 12 65	1.56 - 26 120 ± 4.2 3
Molybdenum	1.14 - 99 ± 4.9 3	1.9 94.7 ± 0 3	
Sodium	100 - 210 102 ± 3.1 27	210 - 502 98 ± 3.3 14	
Nickel	0.055 - 0.096 35 ± 51 21	0.096 - 1.08 103 ± 22 65	1.08 - 1.3 89 ± 2.7 3
Phosphorous	5.7 113 ± 1.4 2		

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TABLE 9 (continued)

RECOVERIES OF ANALYTICAL REFERENCE STANDARDS FOR WATER SAMPLES

Element	Percent Recovery ± Standard Deviation for Various Concentration Levels		
Lead	0.1 - 0.24 55 ± 49 54	0.24 - 0.82 97 ± 5.2 9	0.82 - 1.15 95.7 ± 0 3
Silicon	1 - 2[a] 90 ± 9.5[b] 6[c]	2 - 5 81 ± 2.1 2	
Strontium	0.239 84 ± 5.5 20		
Thorium	No Standards		
Titanium	0.032 106 1	0.054 - 0.6 95 ± 10 56	0.6 - 1.0 105 ± 3.8 3
Vanadium	0.0384 - 0.098 87 ± 20 33	0.098 - 0.72 99 ± 8.8 42	0.72 - 1.2 98 ± 2.9 3
Zinc	0.072 - 0.11 80 ± 31 21	0.11 - 2.07 97 ± 14 65	2.07 - 3.45 97 ± 5 3
Zirconium	0.2 97 ± 2.9 3	0.8 102 ± 1.4 2	
Fluoride	0.1 - 0.4 112 ± 17 11	0.4 - 1.1 97 ± 4.7 6	1.1 - 50 105 ± 16 45

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TABLE 9 (continued)

RECOVERIES OF ANALYTICAL REFERENCE STANDARDS FOR WATER SAMPLES

Element	Percent Recovery ± Standard Deviation for Various Concentration Levels		
Chloride	0.5 107 ± 31 3	5 - 6 98 ± 17 8	6 - 10,000 107 ± 27 63
Nitrate	0.5 - 2 155 ± 47 5	2 - 7.5 108 ± 15 8	7.5 - 250 100 ± 15 42
Sulfate	2 - 5[a] 122 ± 14[b] 5[c]	5 - 25 107 ± 21 13	25 - 1,400 96 ± 11 57
Phosphate	2.5 100 ± 11 3	10.1 - 17.5 108 ± 8.7 9	

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[a] Concentration Range (ppm)
[b] Percent Recovery ± Standard Deviation
[c] Number of samples in set

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TABLE 10

SUMMARY OF NBS STANDARDS RECOVERY (SOLIDS) BY ICAP
(all in ppm)

	NBS 1633 Fly Ash			NBS 1633a Fly Ash			NBS 1645 River Sediment		
	Ref. Value	Analyzed[a]	Rec %	Ref. Value	Analyzed[b]	Rec %	Ref. Value	Analyzed[c]	Rec %
Be	12	8±3	67±25	12	10.9±0.4	91±3	--	--	--
Cd	1.45	11.6±11.2	800±772	1	10.4±8.2	1040±820	10.2	11.7±15.1	115±148
Co	38	46.3±18.2	119±48	46	38±9.5	83±21	8	<5±0	<63
Cr	131	105±15	80±11	196	124±69	63±35	29600	20200±3680	68±12
Cu	128	110±50	86±39	118	117±3	99±3	109	106±4	97±4
K	17200	16770±2750	98±16	18800	18470±305	98±2	12000	12350±71	103±1
Mn	493	405±70	82±14	190	169±8	89±4	785	715±27	91±3
Ni	98	74.5±31.6	76±39	127	119±16	94±13	46	41.5±14.8	90±32
Pb[d]	70	50±25	71±36	72	60±5	83±7	714	740±28	104±4
Sr	1380	1079±33	78±2	830	695±16	84±2	--	--	--
Th	24	28±7	117±29	23	25±3.6	140±14	1.6	<1±0	<63
V	214	164±55	77±26	300	281±7.5	94±3	23.5	27.2±2.8	116±12
Zn	210	189±78	90±37	220	230±37	105±17	1720	1495±304	87±18
Ca	--	--	--	11100	10800±529	97±5	--	--	--
Fe	--	--	--	94000	97600±3990	104±4	113000	110500±4950	98±4
Mg	--	--	--	4550	4343±152	95±3	--	--	--
Mo	--	--	--	29	<43±23	<148	--	--	--
Na	--	--	--	1700	2930±451	166±27	5500	5550±354	101±6
Ti	--	--	--	8000	8070±174	101±2	--	--	--
Al	--	--	--	140000	134700±5130	96±4	--	--	--

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[a] 4 Values
[b] 3 Values
[c] 2 Values
[d] Analysis using atomic absorption

water was very poor; these results were not used in the Plant 9 (Smith) assessment. For several of the spikings, beryllium recoveries were somewhat low. Low level cobalt spikes into 100% sea water were imprecise, and, on the average, low; the assessment team was appraised of the problem. Recoveries of chromium in the two samples spiked from Plant 1 (Elrama) were about 60%; chromium was not important in the assessment for Plant 1. The low level iron recoveries for the Plant 1 (Elrama) and 6 (Powerton) samples were erratic and, on the average, high. The assessment team was cautioned to avoid using data for iron in this concentration range. Recoveries of all the lead spikes were low. As noted in the preceding subsection, selected important samples were rechecked by graphite furnace atomic absorption spectroscopy. Silicon was disregarded in the Plant 9 assessment. In all cases, the assessment team was able to complete the required analysis without using any questionable data.

2.8 RESULTS FOR PERFORMANCE AUDIT SAMPLES

Two performance audit samples, one a liquid and the other a solid, were received from Mr. Alvia Gaskill, Jr., of Research Triangle Institute, on April 26, 1982. Portions of the samples were submitted to Barringer-Magenta for ICAP analyses. Measurements of arsenic and selenium were performed in the ADL laboratories. The results of the analyses were returned to Mr. Gaskill on August 2, 1982. Included with the results was a discussion of the analytical procedures used and the quality control samples that were submitted along with the performance audit samples.

The results obtained for the liquid and solid performance audit samples are shown in Tables 10 and 11, respectively. Based on the quality control samples which were submitted as part of the lot, the ICAP results for several elements were doubtful and a value was not reported. The notes accompanying Tables 9 and 10 discuss the analytical problems. The RTI auditor indicated that the results were satisfactory.

2.9 IDENTIFICATION AND RESOLUTION OF SIGNIFICANT SAMPLING AND ANALYSIS PROBLEMS

As noted previously, a variety of analytical problems were encountered throughout the ongoing QA/QC program. By far the most frequent problem which required corrective action was the appearance of a result which was grossly in error. For example, one member of a triplicate set of standards might have zero recovery while the other two members showed good recovery. In other instances, the results for the analysis of two samples appeared interchanged. These problems were communicated to Barringer-Magenta and resolved either by examination of the raw ICAP data or by reanalyzing retained samples.

From time to time, inter-element interferences and matrix effects were detected. While Barringer-Magenta attempted to correct for known inter-element interferences, certain inter-element effects were observed in the data. Detailed QC analyses sufficient for accurate mathematical corrections were beyond the scope of this program. The general nature of the effects were communicated from time to time to the assessment team so that they would be aware of the limitations of data validity as they were proceding with their assessment. For example, on February 1, 1982, a memorandum was

TABLE 11

SUMMARY OF ANALYTICAL RESULTS
RTI "LIQUID" AUDIT SAMPLE

Element	Concentration (mg/L)[b]	Long-Term Method Performance
Ag	AP[c]	Note 1
Al	AP	Note 2
B	0.047 ± 0.012	Recovery of 100 ± 25% at 0.3 mg/L
Ba	0.037 ± 0.001	Recovery of 100 ± 25% at 1 mg/L
Be	0.017 ± 0.0002	Recovery of 100 ± 25% at 0.02 to 0.1 mg/L
Ca	23.6 ± 0.5	Recovery of 100 ± 25% at 50-500 mg/L
Cd	<0.01	Recovery of 100 ± 25% at 0.1 mg/L
Co	<0.05	Recovery of 100 ± 25% at 0.1-0.3 mg/L
Cr	0.053 ± 0.006	Recovery of 100 ± 25% at 0.2 mg/L[e]
Cu	0.015 ± 0.002	Recovery of 100 ± 25% at 0.2 mg/L
Fe	0.11 ±0.01	Recvoery of 100 ± 25% at 0.3 mg/L
K	<1	Recovery of 100 ± 25% at 30 mg/L
Mg	6.7 ± 0.2	Recovery of 100 ± 25% at 10-500 mg/L
Mn	0.03 ±0.000	Recovery of 100 ± 25% of 0.1-0.3 mg/L
Mo	AP	Note 3
Na	8 ± 0	Recovery of 100 ± 25% at 100-800 mg/L
Ni	0.06 ±0.006	Recovery of 100 ± 25% at 0.1-0.3 mg/L
P	AP	Note 4
Pb[d]	AP	Note 5
Si	AP	Note 6
Sr	0.181 ± 0.002	Recovery of 100 ± 25% at 0.2 mg/L
Th	AP	Note 7
Ti	0.013 ± 0.000	Recovery of 100 ± 25% at 0.1 mg/L
V	0.052 ± 0.002	Recovery of 100 ± 25% at 0.1 mg/L
Zn	0.06 ± 0.006	Recovery of 100 ± 25% at 0.3 mg/L
Zr	AP	Note 8
As[d]	0.079 ± 0.003	Recovery of 100 ± 25% at 0.080 mg/L
Se[d]	0.010 ± 0.001	Recovery of 100 ± 25% at 0.010 mg/L

(a) Based on analyses of blind standards sent with each lot of samples to be analyzed. (See cover letter.)

(b) Mean and standard deviation for triplicate analyses.

(c) Analysis problem. (See cover letter and series of explanatory notes attached to this table.)

(d) These elements were analyzed by AA. The remainder by ICAP.

(e) For Cr standards at 0.017 mg/L, results raning from <0.010-0.030 mg/L have been obtained.

Source: Arthur D. Little, Inc.

NOTES FOR TABLE 11 DATA

Note 1: The performance for Ag recovery of 100 ± 25% at 0.050 mg/L was not met. Barringer reported a value of <0.005 mg/L for the RTI sample. We are aware of at least one instance of low recovery on blind standards. We are investigating these values, since Ag is a relatively important element with regard to the proposed primary drinking water criteria.

Note 2: Throughout the program, recovery of Al has been variable in the range of 0 to 200% for 0.2-1 mg/L concentration range. Recovery of blind standards for this analysis set showed very poor recovery. Barringer reported a value of <0.01 mg/L. Since Al is not in the proposed primary or secondary drinking water criteria and is not expected to be a major FGC waste tracer, it has been viewed as a low priority element and no corrective action has been taken.

Note 3: Barringer reported a value of < 0.3 mg/L for the RTI sample. The reference value for the blind standard is below the ICAP detection limit. We are investigating the behavior of Mo at higher levels.

Note 4: Barringer reported a value of <0.6 mg/L. This element is considered low priority because it is not in the proposed drinking water criteria and it is not expected to be a good FGC waste tracer. In addition, phosphate is measurable in the liquids using ion chromatography.

Note 5: The performance target for Pb recovery of 100 ± 25% at 0.1-0.8 mg/L was not met for this set of samples. A recovery of <50% at 0.1 mg/L was observed. Barringer reported a value of <0.05 mg/L. Since this is an important element with regard to the proposed drinking water criteria, reanalysis of this particular set of samples has been requested of Barringer-Magenta.

Note 6: This is regarded as a low priority element. No standards containing Si were sent with the particular batch of samples. Barringer reported a value of <0.05 mg/L. We are currently in the process of investigating recovery of blind standards.

Note 7: This is regarded as a low priority element. No standards containing Th have been analyzed during the program. Barringer reported a value of <0.01 mg/L.

Note 8: This is regarded as a low priority element. No standards containing Zr have been analyzed during the program. Barringer reported a value of <0.05 mg/L.

TABLE 12

SUMMARY OF ANALYTICAL RESULTS
RTI "SOLID" AUDIT SAMPLE

Element	Concentration (mg/L)[b]	Long-Term Method Performance[a]
Ag	AP[c]	Note 1
Al	85000 ± 4200	Recovery of 100 ± 25% at 140000 μg/g
Be	1.45 ± 0.04	Recovery of 100 ± 25% at 12 μg/g
Ca	24500 ± 1100	Recovery of 100 ± 25% at 11000 μg/g
Cd	AP	Note 2
Co	<5	Recovery of 100 ± 50% at 50 μg/g
Cr	2, <1, <1	Recovery of 100 ± 50% at 200 μg/g
Cu	90 ± 3	Recovery of 100 ± 25% at 100 μg/g
Fe	51000 ± 5000	Recovery of 100 ± 25% at 94000 μg/g
K	21300 ± 700	Recovery of 100 ± 25 at 12000 μg/g
Mg	12800 ± 600	Reocvery of 100 ± 25% at 4500 μg/g
Mn	900 ± 100	Recovery of 100 ± 25% at 190 μg/g
Mo	AP	Note 3
Na	AP	Note 4
Ni	7 ±1	Recovery of 100 ± 50% at 45 μg/g
P	AP	Note 5
Pb[d]	140 ± 20	Recovery of 100 ± 50% at 70 μg/g
Sr	342 ± 6	Recovery of 100 ± 25% at 800 μg/g
Th	10 ± 7	Recovery of 100 ± 50% at 25 μg/g
Ti	5200 ± 400	Recovery of 100 ± 25% at 8000 μg/g
V	143 ± 7	Recovery of 100 ± 25% at 25 μg/g
Zn	360 ± 20	Recovery of 100 ± 25% at 220 μg/g
Zr	AP	Note 6
As[d]	106 ± 7	Recovery of 100 ± 25% at 70 μg/g
Se[d]	0.20 ± 0.05	Recovery of 100 ± 30% at 10 μg/g

(a) Based on analyses of blind standards sent with each lot of samples to be analyzed. (See cover letter.)

(b) Mean and standard deviation for triplicate analyses.

(c) Analysis problem. (See cover letter and series of explanatory notes attached to this table.)

(d) These elements were analyzed by AA. The remainder by ICAP.

Source: Arthur D. Little, Inc.

NOTES FOR TABLE 12 DATA

Note 1: No value for Ag is available for the blind standards we have used, and thus, recovery is not known. Barringer reported a value of <0.5µg/g for the RTI check sample.

Note 2: Our recovery target of 100 ± 25% at 10 µg/g was not met. Barringer reported a value of <1 µg/g for the RTI check sample. Variable Cd recoveries are under investigation.

Note 3: The reference values available for the blind standard we have used are just at the ICAP detection limit. Reliable recovery data is thus not available. Barringer reported a value of <30 µg/g for the RTI check sample. Mo recoveries are under investigation.

Note 4: Our recovery target of 100 ± 25% at 5500 µg/g was met for river sediment blind standards but not for flyash blind standards. This problem is under review. Barringer reported a value of 23200 ± 900 µg/g for the RTI check sample.

Note 5: Reference values for P in our blind standards are not available and thus recovery is unknown. Barringer reported a value of 1380 ± 50 µg/g.

Note 6: Reference values for Zr in our blind standards are not available and thus recovery is unknown. Barringer reported a value of 121 ± 7 µg/g for the RTI check sample.

submitted which pointed out a number of problems which had been observed. They included:

- Values for vanadium were much lower in the presence of high levels of magnesium. In the presence of 80 ppm or less of Mg, recoveries of V were observed to be 84 ±12%. However, for levels of Mg higher than 80 ppm, V recoveries decreased, e.g., at 159 ppm Mg a recovery of 7% was observed for V.

- Levels of Mg above 80 ppm were also found to depress the recovery of chromium.

- Measured concentrations of aluminum in samples containing calcium in the vicinity of 800 ppm were found to be high by a factor of 1-3 when Al was present in the 0.2 - 1 ppm range. The enhancement of Al resulted from the fact that Al is measured at an emission line located between two closely spaced, intense calcium lines. It was recommended that the assessment team request reanalysis of selected samples for chromium or vanadium if the values for those samples were deemed to be important in the assessment effort.

The resolution of other ICAP analysis problems was reported in a memorandum dated July 30, 1982.

- High values of silver were observed in certain samples of an analyses lot including several blanks. The analyses were repeated, and no silver was found in any of the samples. The problem was traced to an incorrect value for a silver reference standard.

- Another interaction between chromium and magnesium which had been detected was finally attributed to a mechanical problem in the ICAP optics. Barringer-Magenta corrected the program and reanalyzed the set of samples in question.

ATTACHMENT 1

SUMMARY OF ICAP SPIKE RECOVERIES

ICAP SPIKE RECOVERIES

ELEMENT: 7 SILVER
DET. LIMIT: <0.005 <0.01

Type of Sample		Spike Conc.(ppm)		#Samples	% Recov.	S.D.	% RSD
ERA 8301 (1:100)	IN 100 PC SEA			0			
ERA 8301 (1:100)	IN 10 PC SEA			0			
ERA 8301 (1:10)	IN 10 PC SEA			0			
OTHERS	IN 100 PC SEA	0.05	0.1	3	74.3	6.03	8.12
PLANT ONE SPIKES				0			
PLANT SIX SPIKES				0			
PLANT THREE SPIKES				0			

ELEMENT: 8 ALUMINUM
DET. LIMIT: <0.01 <0.1

ERA 8301 (1:100)	IN 100 PC SEA			0			
ERA 8301 (1:100)	IN 10 PC SEA			0			
ERA 8301 (1:10)	IN 10 PC SEA			0			
OTHERS	IN 100 PC SEA			0			
PLANT ONE SPIKES		0.24	0.24	2	138	124	89.9
PLANT SIX SPIKES				0			
PLANT THREE SPIKES				0			

ELEMENT: 9 BORON
DET. LIMIT: <0.004 <0.02

ERA 8301 (1:100)	IN 100 PC SEA			0			
ERA 8301 (1:100)	IN 10 PC SEA			0			
ERA 8301 (1:10)	IN 10 PC SEA			0			
OTHERS	IN 100 PC SEA	2	2	3	90.2	2.47	2.74
PLANT ONE SPIKES				0			
PLANT SIX SPIKES				0			
PLANT THREE SPIKES				0			

ELEMENT: 10 BARIUM
DET. LIMIT: <0.005

ERA 8301 (1:100)	IN 100 PC SEA			0			
ERA 8301 (1:100)	IN 10 PC SEA			0			
ERA 8301 (1:10)	IN 10 PC SEA	4.4	4.4	2	2.15	0.177	8.23
OTHERS	IN 100 PC SEA			0			
PLANT ONE SPIKES				0			
PLANT SIX SPIKES				0			
PLANT THREE SPIKES				0			

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ELEMENT: 11 BERYLLIUM
DET. LIMIT: <0.0005

Type of Sample	Spike Conc.(ppm)		#Samples	% Recov	S.D.	% RSD
ERA 8301 (1:100) IN 100 PC SEA	0.1	0.1	8	72.1	6.64	9.21
ERA 8301 (1:100) IN 10 PC SEA	0.1	0.1	9	90.2	4.58	5.08
ERA 8301 (1:10) IN 10 PC SEA	1	1	2	71.8	0.354	0.493
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	0.04	0.04	2	67.2	0.212	0.315
PLANT SIX SPIKES	0.01	0.01	2	84	5.66	6.74
PLANT THREE SPIKES	0.2	0.2	1	100	0	0

ELEMENT: 12 CALCIUM
DET. LIMIT: <0.01

ERA 8301 (1:100) IN 100 PC SEA			0			
ERA 8301 (1:100) IN 10 PC SEA			0			
ERA 8301 (1:10) IN 10 PC SEA			0			
OTHERS IN 100 PC SEA	200	200	3	108	2	1.85
PLANT ONE SPIKES	166	166	2	97.9	24.3	24.8
PLANT SIX SPIKES			0			
PLANT THREE SPIKES			0			

ELEMENT: 13 CADMIUM
DET. LIMIT: <0.01 <0.1

ERA 8301 (1:100) IN 100 PC SEA	0.09	0.09	8	75	15.4	20.5
ERA 8301 (1:100) IN 10 PC SEA	0.09	0.09	9	99.9	16.6	16.6
ERA 8301 (1:10) IN 10 PC SEA	0.9	0.9	2	85	3.96	4.66
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	0.062	0.062	2	105	11.5	11
PLANT SIX SPIKES			0			
PLANT THREE SPIKES	0.18	0.18	1	88.9	0	0

ELEMENT: 14 COBALT
DET. LIMIT: <0.05 <0.1

Type of Sample	Spike Conc.(ppm)		# Samples	% Recov.	S.D.	% RSD
ERA 8301 (1:100) IN 100 PC SEA	0.255	0.255	8	62.3	35.8	57.5
ERA 8301 (1:100) IN 10 PC SEA	0.255	0.255	9	96.3	64.2	66.7
ERA 8301 (1:10) IN 10 PC SEA	2.55	2.55	2	97.5	16.3	16.7
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	0.424	0.424	2	117	8.49	7.26
PLANT SIX SPIKES			0			
PLANT THREE SPIKES	0.51	0.51	1	112	0	0

ELEMENT: 15 CHROMIUM
DET. LIMIT: <0.01 <0.05

ERA 8301 (1:100) IN 100 PC SEA	0.25	0.25	8	118	23	19.5
ERA 8301 (1:100) IN 10 PC SEA	0.25	0.25	9	118	14.6	12.4
ERA 8301 (1:10) IN 10 PC SEA	2.5	2.5	2	92.7	14.6	15.7
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	0.315	0.315	2	60.4	44.9	74.3
PLANT SIX SPIKES	0.01	0.01	2	100	0	0
PLANT THREE SPIKES	0.5	0.5	1	104	0	0

ELEMENT: 16 COPPER
DET. LIMIT: <0.008 <0.02

ERA 8301 (1:100) IN 100 PC SEA	0.2	0.2	8	84.4	8.41	9.96
ERA 8301 (1:100) IN 10 PC SEA	0.2	0.2	9	90.4	7.81	8.64
ERA 8301 (1:10) IN 10 PC SEA	2	2	2	85.1	2.19	2.57
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	0.19	0.19	2	95.8	4.45	4.65
PLANT SIX SPIKES	0.009	0.009	2	111	0	0
PLANT THREE SPIKES	0.4	0.4	1	101	0	0

ELEMENT: 17 IRON
DET. LIMIT: <0.01

Type of Sample	Conc. (ppm)		#Samples	% Recov.	S.D.	% RSD
ERA 8301 (1:100) IN 100 PC SEA	0.34	0.34	7	92	29.8	32.4
ERA 8301 (1:100) IN 10 PC SEA	0.34	0.34	9	86	28.1	32.7
ERA 8301 (1:10) IN 10 PC SEA	3.4	3.4	2	90.9	1.7	1.87
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	0.11	0.11	1	245	0	0
PLANT SIX SPIKES	0.04	0.04	2	213	159	74.6
PLANT THREE SPIKES	0.68	0.68	1	104	0	0

ELEMENT: 18 POTASSIUM
DET. LIMIT: <1

ERA 8301 (1:100) IN 100 PC SEA			0			
ERA 8301 (1:100) IN 10 PC SEA			0			
ERA 8301 (1:10) IN 10 PC SEA			0			
OTHERS IN 100 PC SEA	148	148	3	123	3.79	3.08
PLANT ONE SPIKES	7.87	78.7	2	142	14.1	9.93
PLANT SIX SPIKES			0			
PLANT THREE SPIKES			0			

ELEMENT: 19 MAGNESIUM
DET. LIMIT: <0.01

ERA 8301 (1:100) IN 100 PC SEA			0			
ERA 8301 (1:100) IN 10 PC SEA			0			
ERA 8301 (1:10) IN 10 PC SEA			0			
OTHERS IN 100 PC SEA	498	498	3	95.1	5.9	6.2
PLANT ONE SPIKES	23.9	23.9	2	80.3	19	23.7
PLANT SIX SPIKES			0			
PLANT THREE SPIKES			0			

ELEMENT: 20 MANGANESE
DET. LIMIT: <0.01

ERA 8301 (1:100) IN 100 PC SEA	0.26	0.26	8	82.7	14.1	17
ERA 8301 (1:100) IN 10 PC SEA	0.26	0.26	9	104	8.18	7.87
ERA 8301 (1:10) IN 10 PC SEA	2.6	2.6	2	79.6	2.69	3.38
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	0.1	0.1	1	100	0	0
PLANT SIX SPIKES			0			
PLANT THREE SPIKES	0.52	0.52	1	113	0	0

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ELEMENT: 21 MOLYBDENUM
DET. LIMIT: <0.2 <0.4

Type of Sample	Conc.(ppm)		# Samples	% Recov.	S.D.	% RSD
ERA 8301 (1:100) IN 100 PC SEA			0			
ERA 8301 (1:100) IN 10 PC SEA			0			
ERA 8301 (1:10) IN 10 PC SEA	1.9	1.9	2	92.1	11.2	12.2
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES			0			
PLANT SIX SPIKES			0			
PLANT THREE SPIKES	0.38	0.38	1	105	0	0

ELEMENT: 22 SODIUM
DET. LIMIT: <1

ERA 8301 (1:100) IN 100 PC SEA			0			
ERA 8301 (1:100) IN 10 PC SEA			0			
ERA 8301 (1:10) IN 10 PC SEA			0			
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	24.1	80.3	2	104	5.94	5.71
PLANT SIX SPIKES			0			
PLANT THREE SPIKES			0			

ELEMENT: 23 NICKEL
DET. LIMIT: <0.05

ERA 8301 (1:100) IN 100 PC SEA	0.13	0.13	8	94.3	16.4	17.4
ERA 8301 (1:100) IN 10 PC SEA	0.13	0.13	9	109	31.7	29.1
ERA 8301 (1:10) IN 10 PC SEA	1.3	1.3	2	83.5	7.07	8.47
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	0.27	0.27	2	87.1	13.1	15
PLANT SIX SPIKES			0			
PLANT THREE SPIKES	0.26	0.26	1	92.3	0	0

ELEMENT: 24 PHOSPHORUS
DET. LIMIT: <0.5 <1

ERA 8301 (1:100) IN 100 PC SEA		0
ERA 8301 (1:100) IN 10 PC SEA		0
ERA 8301 (1:10) IN 10 PC SEA		0
OTHERS IN 100 PC SEA		0
PLANT ONE SPIKES		0
PLANT SIX SPIKES		0
PLANT THREE SPIKES		0

ELEMENT: 25 LEAD
DET. LIMIT: <0.05 <0.1

Type of Sample	Conc.(ppm)		# Samples	% Recov.	S.D.	% RSD
ERA 8301 (1:100) IN 100 PC SEA	0.115	0.115	8	65.2	32.7	50.2
ERA 8301 (1:100) IN 10 PC SEA	0.115	0.115	9	57.9	30.6	52.8
ERA 8301 (1:10) IN 10 PC SEA	1.15	1.15	1	43.5	0	0
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	0.21	0.21	2	23.8	0	0
PLANT SIX SPIKES			0			
PLANT THREE SPIKES	0.23	0.23	1	21.7	0	0

ELEMENT: 26 SILICON
DET. LIMIT: <0.05 <0.1

ERA 8301 (1:100) IN 100 PC SEA			0			
ERA 8301 (1:100) IN 10 PC SEA			0			
ERA 8301 (1:10) IN 10 PC SEA			0			
OTHERS IN 100 PC SEA	2	2	3	3.83	2.31	60.3
PLANT ONE SPIKES			0			
PLANT SIX SPIKES			0			
PLANT THREE SPIKES			0			

ELEMENT: 27 STRONTIUM
DET. LIMIT: <0.001

ERA 8301 (1:100) IN 100 PC SEA			0			
ERA 8301 (1:100) IN 10 PC SEA			0			
ERA 8301 (1:10) IN 10 PC SEA			0			
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES			0			
PLANT SIX SPIKES	0.12	0.12	2	81.3	1.77	2.18
PLANT THREE SPIKES			0			

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ELEMENT: 28 THORIUM
DET. LIMIT: <0.01 <0.1

Type of Sample	Conc.(ppm)		# Samples	% Recov.	S.D.	% RSD
ERA 8301 (1:100) IN 100 PC SEA		0				
ERA 8301 (1:100) IN 10 PC SEA		0				
ERA 8301 (1:10) IN 10 PC SEA		0				
OTHERS IN 100 PC SEA		0				
PLANT ONE SPIKES		0				
PLANT SIX SPIKES		0				
PLANT THREE SPIKES		0				

ELEMENT: 29 TITANIUM
DET. LIMIT: <0.005 <0.01

ERA 8301 (1:100) IN 100 PC SEA	0.1	0.1	8	73.5	11.3	15.4
ERA 8301 (1:100) IN 10 PC SEA	0.1	0.1	9	91	15.3	16.8
ERA 8301 (1:10) IN 10 PC SEA	1	1	2	80.4	6.36	7.91
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	0.054	0.054	2	88.9	5.23	5.88
PLANT SIX SPIKES			0			
PLANT THREE SPIKES	0.2	0.2	1	108	0	0

ELEMENT: 30 VANADIUM
DET. LIMIT: <0.005 <0.01

ERA 8301 (1:100) IN 100 PC SEA	0.12	0.12	8	84.2	13.5	16
ERA 8301 (1:100) IN 10 PC SEA	0.12	0.12	9	101	9.71	9.61
ERA 8301 (1:10) IN 10 PC SEA	1.2	1.2	2	90.3	6.08	6.73
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	0.135	0.135	1	86.7	0	0
PLANT SIX SPIKES	0.026	0.026	2	38.5	10.9	28.3
PLANT THREE SPIKES	0.24	0.24	1	101	0	0

ELEMENT: 31 ZINC
DET. LIMIT: <0.05

ERA 8301 (1:100) IN 100 PC SEA	0.345	0.345	8	81.6	34.2	41.9
ERA 8301 (1:100) IN 10 PC SEA	0.345	0.345	9	109	7.31	6.71
ERA 8301 (1:10) IN 10 PC SEA	3.45	3.45	2	82.7	9.83	11.9
OTHERS IN 100 PC SEA			0			
PLANT ONE SPIKES	0.3	0.3	2	91.7	2.33	2.54
PLANT SIX SPIKES			0			
PLANT THREE SPIKES	0.69	0.69	1	94.2	0	0